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## Sixth Biennial Cheese Industry Conference

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*Gay H. Richardson*  
*NFS Bldg 318*

*Publ 2 JDS - Rec.*

# CHEESE CONFERENCE SCHEDULE

TUESDAY, AUGUST 28, 1984

9:00 - 10:00 Registration, Eccles Conference Center Registration *Tyrosine tests in UF concs. - Enzyme activity after heating.*

All conference sessions will be in ECC Auditorium 216 except where indicated otherwise.

THEME: OUR CHANGING INDUSTRY

10:00-10:15	Welcome to Utah State University	Chairman: Blaine Rich
10:15-10:55	Impact of Government Policies on the Cheese Industry	
10:55-11:30	California Cheese Industry and California Cheese Markets	Bartell Jensen
11:30-12:00	Market Potential for Specialty Cheese	Bob Sheldon
12:00- 1:30	Lunch, Carousel Square, University Center	W. A. Holloran

## Afternoon Session

THEME: CULTURES, THE HEART OF CHEESE MAKING Chairman: Robert Olsen

1:30- 2:10	Development of a Defined Single Strain System in New Zealand	Howard A. Heap
2:10- 2:50	Dairy Cultures and Enzymes: Historical Development and State of the Art	Alan Huggins
2:50- 3:10	Snacks and Conversation	
3:10- 3:50	Evaluation of Commercially Available Italian Cheese Starter Media	William Sandine
3:50- 4:30	Getting the most "Clot" out of Your Milk	G. H. Richardson
6:00- 4:44	Steak Fry, Malibu Site, Logan Canyon bus departs motel at 5:30 p.m.	

WEDNESDAY, AUGUST 29, 1984

THEME: IMPROVING POTENTIAL FOR PROFIT Chairman: Reed Ernstrom

8:30- 9:10	Effect of Standardization of Milk on the Profitability of Mozzarella Cheese	David Barbano
9:10- 9:50	Innovation Within Federal Cheese Regulations	Merrill Thompson
9:50-10:05	Snacks and Conversation	
10:05-10:45	Advances in the Genetic Engineerings of Rennet (Chymosin)	H. Robert Goltz
10:45-11:20	Somatic Cells and the Effect of Mastitis on Cheese Yields	David Barbano
11:20-12:00	Helping Milk Producers Control Mastitis and Reduce Somatic Cell Counts	A. N. Bringe
12:00- 1:30	Lunch, Carousel Square, University Center	

## Afternoon Session

THEME: WHERE IS ULTRAFILTRATION LEADING US?

Chairman: Jeffery Kondo

- |            |   |                |
|------------|---|----------------|
| 1:30- 2:15 | On-farm Ultrafiltration of Milk:<br>A National Study                            | A. J. Luksas   |
| 2:15- 3:00 | Properties of Products from Ultrafiltered<br>Whole Milk                         | C. A. Ernstrom |
| 3:15- 3:50 | A New Enzyme Reactor System for Hydrolyzing<br>Lactose in Milk or Whey Permeate | Bruce Goldberg |
| 3:50- 4:40 | Comparison of End Product and Component<br>Pricing Proposals for Cheese Milk    | R. J. Brown    |
| 4:40- 5:30 | Cheese Quality and Variety  | Robert Olsen   |

THURSDAY, AUGUST 30, 1984

THEME: IMPROVING QUALITY AND EFFICIENCY

Chairman: Joe Heap

- |             |   |                      |
|-------------|---|----------------------|
| 8:30- 9:10  | Improved and Rapid Methods for<br>Enumerating Bacteria  | Robert Young         |
| 9:10- 9:55  | New Applications for Electrical<br>Impedence Measurements: Starter Activity,<br>Abnormal Milk Detection, Antibiotic<br>Detection, Coliform Counts | G. H. Richardson     |
| 9:55-10:30  | What's Happening with Antibiotic Testing  | R. J. Brown          |
| 10:30-12:00 | Demonstration of Antibiotic Tests and<br>Bactomatic Instrument  | Genesis-Laboratories |
|             | Charm Penicillin Assays   | Bactomatic           |
|             | G. B. Fermentation Industries   | C.E.M.               |
|             |   | Angenics-(Spot test) |

August 28, 1984

Utah State University  
Logan, Utah

### MARKET POTENTIAL FOR SPECIALTY CHEESE

William A. Holloran  
"Stauffer Cheese Inc."  
Blue Mounds, Wisconsin

By accident, early man discovered that fluid milk could be turned into solid cheese. This discovery has been important for thousands of years. It has given us a nutritious food that is in compact, convenient form and relatively stable in keeping quality. Simply defined, cheese is the solid portion of milk separated from the whey portion.

### VARIETIES OF CHEESE

Over seven-hundred various named cheeses are found throughout the world. However, all of these vast named varieties are just merely variations of three manufacturing methods. By controlling the natural miracle, which changes milk into solid cheese, man has been able to produce this wide variety of names, flavors, and textures.

The distinctive difference affecting and causing variation of the color, shape, texture, aroma, etc., are due to:

1. Kind of milk used (cow-sheep-goat-skim-cream)
2. Geographic conditions affecting the milk-giving animals feed. This is caused by weather, soil conditions, type of grass and water, etc.
3. Method of coagulating, cutting the curd, cooking (heat & time), and forming the curd.
4. Addition of bacteria, molds, artificial color, salt, or other seasonings.
5. The conditions of curing (aging) or ripening such as time, temperature, humidity.

### SPECIALTY CHEESE - DEFINED

Specialty cheese has been defined as "any item not in national distribution". At one time, specialty cheeses were considered to be only the imports. However, my definition is: "any item not included in the major U.S.D.A. categories". That is: American (cheddar - jack - colby - washed curd), Italian (primarily mozzarella), and Swiss.



## BACKGROUND

Survival is the mother of invention and innovation. The bottom line, profit & loss, is the name of the game in any business. In the 1960's I was a young corporate supermarket deli executive. Part of my report card was based upon my divisions percentage to the total business. I was continually striving to increase this percent to total. One method that I discovered was to find and create a need for items that did not exist that did not affect other items. Also, it was urgent that I increased our volume, thru our deli production facility, to increase the profit of the division. By increasing production, with our adding labor, our unit costs were reduced and profits substantially increased. This was accomplished by adding new items, particularly many new specialty cheeses.

Monterey Jack Cheese was popular in the Los Angeles area. It was not so in other parts of the country. In those days, getting a Wisconsin cheesemaker to make jack was almost impossible. They thought we were nuts and that jack cheese was junk. The majority of our jack was produced from the western region. Twenty five years ago I would consider jack to be a type of specialty item. It was not popular nationally. Today, jack is significant manufactured item.

Our service deli's were selling a considerable amount of string cheese and red rind muenster. Consequently, I started packing string and red rind muenster. The manufacturer of our string, Gardenia Cheese Company, asked me to package string for them. Today, packaged string cheese is a very popular specialty item.

## U.S. CHEESE CONSUMPTION/TRENDS

Cheese consumption, in the United States, was in excess of four billion pounds in 1983. It is estimated that 1984 consumption could expand to almost five billion. The industry has been growing at an annual rate of about 3.2%.

For the past 25 years, there has been an uninterrupted yearly increase in the per capita consumption of cheese. This increase is expected to continue. In 1960, it was about 8.3 pounds per person, and in 1983 it was 20.6 pounds. It is expected to raise, in 1984, to over 22 pounds. American types (cheddar - jack - colby) account for about 60% of the market, while the Italian types, primarily mozzarella account for about 25%, Swiss cheese contributes around 6% and all other varieties for the remainder.

U.S. per capita consumption climbed (all cheese) 143% from 8.3 lbs to 20.6, 1960 to 1983. This growth rate is still continuing. It is significant when compared to European highs of 20 to 30 pounds, considering U.S. population growth has been relatively stagnant. The above indicates that young people are consuming more cheese than their counterparts, 25 years ago.

Although the basic types (American - Italian - Swiss) used in casseroles and sandwiches are still the largest segment of the market, a growing number of consumers are becoming more familiar with other fine specialty cheeses now widely available.

Increased international travel, coupled with U.S. society becoming more affluent, due to rising consumer incomes, are attributed for the U.S. consumer demanding cheese varieties out of the ordinary.

Supermarkets have recognized this new consumer awareness and are devoting more case space and promotional activity to the basic types and particularly to the specialty items. Specialty items command a much higher gross profit, without hurting the demand items, and therefore are receiving considerable attention.

America's per capita consumption has more than doubled since U.S.D.A. first started keeping statistics in 1950. According to the national cheese institute, every person in the United States is consuming 60 percent more cheese today, than 10 years ago. Still, Americans have a long way to go before reaching European highs of 35 pounds.

In a recent survey by "Progressive Grocer", retailers were asked to rate the growth potential of various products, in the deli, over the next ten year. Domestic cheese took first place.

#### MARKET SEGMENTATION

The big users of cheese are in families of one or two members. They buy more of the process types, and nearly twice as much as natural - per capita - as families of six or more.

Younger housewives buy more of the process types than natural. Older housewives buy twice as much natural as process types.

The retired and other non-workers are the poorest users of processed types, but the best users of natural cheese. White collar workers are better users than blue collar workers.

Employment of the housewife has little effect on cheese purchases.

Non-whites purchase only about one-third as much cheese as whites, per 1,000 capita, particularly specialty cheese.

Family composition doesn't have much effect on per capita purchases of the process types, but families with no children buy about twice as much natural cheese per capita as those with children.

Foreign born have the highest ratio of natural cheese to the process types. People of the Jewish Faith are the best cheese consumers, both natural and process types.

#### MARKET POTENTIAL INDUSTRY VALUE

The large demand for cheese is from the basic American category. However, this category is the most competitive in the industry. Sales and profits are hampered by the fierce competition from the category. Years ago, at the Olympia Cheese Company, I was faced with tough competition, from the block manufacturers, and turned to the manufacture of various natural specialty items. With the introduction of such items as pepper jack, onion jack, smoked salmon cheddar, chili cheese, string cheese, etc., our sales and profits considerably improved. We were no longer at the mercy of the block market. Other plants have found the production of natural specialty and process items to be a very valuable alternative to just normal blocks of cheddar or jack. Cheese sales are generated from demand, semi-demand, and impulse. Specialty cheese sales are primarily generated from semi-demand and impulse area. These areas are especially attractive for the supermarket retailer as they do not distract from the demand items and provide the retailer with added sales and higher gross profits. This same advantage also applies to the cheese industry and the potential for specialty items is therefore very bright.

#### CONCLUSION

From 1981 to 1983 the basic types (American) only increased (production) about 11%. However, other types increased about 36%. Cold pack cheeses, which are a specialty type, skyrocketed 118%. This group is reported, U.S.D.A., in the basic American group. It can then be concluded that specialty items are becoming a substantial industry factor in U.S. cheese consumption and improved industry sales and profits.

The major problem is: Schreiber has just introduced a new specialty cheese item (smoked chocolate covered limburger "with nuts"). Kraft finds it and now the advantage of the specialty contribution is gone because the market just isn't large enough for more th

EXHIBIT IU.S. CHEESE PRODUCTION

(POUNDS)

	<u>1981</u>	<u>1982</u>	<u>1983</u>
AMERICAN (CHEDDAR - JACK COLBY - WASHED CURD)	2,642,263,000	2,752,298,000	2,927,637,000
ITALIAN	994,398,000	1,087,781,000	1,200,204,000
MOZZARELLA* (INCLUDED IN ABOVE TOTAL ITALIAN)	684,914,000	762,486,000	861,592,000
OTHER	<u>66,596,000</u>	<u>92,396,000</u>	<u>90,632,000</u>
TOTAL U.S.	4,277,561,000	4,539,822,000	4,818,449,000

EXHIBIT IIU.S. PRODUCTION "PROCESSED CHEESE"

(INCLUDES COLD PACK)

	<u>1981</u>	<u>1982</u>	<u>1983</u>
PROCESSED CHEESE	1,723,567,000	1,702,943,000	1,936,783,000
COLD PACK	51,018,000	66,022,000	111,276,000

SOURCE: U.S.D.A. "DAIRY SITUATION"  
MARCH 1984

EXHIBIT IIIU.S. PER CAPITA CIVILIAN CHEESE CONSUMPTION  
(POUNDS)

	<u>1960</u>	<u>1976</u>	<u>1980</u>	<u>1983</u>
AMERICAN		8.98	9.68	11.61
ITALIAN		3.60	4.47	5.33
MOZZARELLA*		2.34	3.05	3.71
(*INCLUDED IN TOTAL ITALIAN)				
OTHER		<u>3.12</u>	<u>3.45</u>	<u>3.66</u>
TOTAL U.S.	8.30	15.70	17.60	20.60

EXHIBIT IVU.S. CIVILIAN COMMERCIAL DISAPPEARANCE OF CHEESE  
(POUNDS)

	<u>1978</u>	<u>1980</u>	<u>1983</u>
AMERICAN	2,064,700,000	2,023,900,000	2,083,200,000
OTHER	<u>1,655,500,000</u>	<u>1,827,900,000</u>	<u>2,133,300,000</u>
TOTAL U.S.	3,720,000,000	3,851,800,000	4,216,500,000

SOURCE: U.S.D.A. "DAIRY SITUATION"  
MARCH 1984

# IMPACT OF GOVERNMENT POLICIES ON THE CHEESE INDUSTRY

AUGUST 28, 1984

JAMES L. REEVES

TO DISCUSS THE IMPACT OF GOVERNMENT POLICIES ON THE CHEESE INDUSTRY ONE MUST COME TO GRIPS WITH THE QUESTION, "WHAT IS THE CHEESE INDUSTRY?"

IN MY JUDGMENT THE CHEESE INDUSTRY IS MADE UP OF THREE DISTINCT SEGMENTS. FIRST THE PRODUCER WHO FURNISHES THE RAW MATERIAL MILK FROM WHICH CHEESE IS MADE. SECONDLY IS THE MANUFACTURING AND PROCESSING LINK THAT CONVERTS THE MILK TO FINISHED CHEESE PRODUCTS AND THIRDLY THERE IS THE SALES AND MARKETING SEGMENT THAT MOVES THE PRODUCT TO THE POINT OF CONSUMPTION.

WHEN WE DISCUSS THE IMPACT OF GOVERNMENT POLICIES UPON THE CHEESE INDUSTRY WE MUST ALWAYS BEAR IN MIND THAT SOME OF THESE IMPACTS MAY HAVE BEEN DISAGREEABLE FROM THE STANDPOINT OF ONE PARTICULAR SEGMENT, BUT VERY DESIRABLE FROM ANOTHER. MY EFFORT HERE TODAY WILL BE TO DEFINE THE MAJOR POLICIES THAT HAVE BEEN IN EFFECT FOR THE PAST THREE DECADES, THE LAWS AND REGULATIONS THAT HAVE IMPLEMENTED THESE POLICIES AND THE IMPACT THAT THEY HAVE HAD ON THE THREE SEGMENTS OF THE CHEESE INDUSTRY.

THE GOVERNMENTAL POLICY THAT MOST AFFECTED THE CHEESE INDUSTRY - INDEED THE DAIRY INDUSTRY - WAS THE DECISION BY CONGRESS TO DIRECTLY SUPPORT THE LEVEL OF MILK PRICES THROUGH A PURCHASE OR LOAN PROGRAM. WHILE PRIOR AGRICULTURAL LEGISLATION ADDRESSED THE PROBLEM OF SUPPORTING MILK PRICES, THE AGRICULTURAL ADJUSTMENT ACT OF 1949 WAS THE FIRST FEDERAL LAW REQUIRING THE

SECRETARY OF AGRICULTURE TO SUPPORT MILK PRICES TO PRODUCERS FOR MILK AND BUTTERFAT AT SUCH LEVELS BETWEEN 75 TO 90 PERCENT OF PARITY AS WOULD ASSURE AN ADEQUATE SUPPLY OF MILK AND DAIRY PRODUCTS. IT WAS HIGHLY SIGNIFICANT THAT NO LIMIT WAS PLACED ON THE AMOUNT OF DAIRY PRODUCTS THAT WOULD BE PURCHASED TO CARRY OUT THIS CONGRESSIONAL MANDATE.

I THINK IT MIGHT BE WELL TO DIGRESS FOR A MOMENT AND DISCUSS THE CONDITIONS THAT BROUGHT ABOUT THE PASSAGE OF THE 1949 AGRICULTURAL ACT. THE CONGRESSIONAL DEBATE REVEALS THAT THERE WAS, IN FACT, A SERIOUS DANGER THAT MANY DAIRY FARMERS AND DAIRY PROCESSORS WERE IN DANGER OF BANKRUPTCY. THE U.S. WAS JUST EMERGING FROM WORLD WAR II WHEN BOTH MILK PRODUCTION AND THE CONSTRUCTION OF NEW PROCESSING PLANTS HAD BEEN ENCOURAGED BY GOVERNMENT SUBSIDIES. WITH THE WAR OVER MARKETS WERE DECLINING RAPIDLY.

BEAR IN MIND THAT DURING WORLD WAR II THE U.S. WAS FEEDING NOT ONLY THE LARGEST ARMY EVER ASSEMBLED, BUT HALF OF THE POPULATION OF ENGLAND AND WESTERN EUROPE.

AS AGRICULTURAL PLANTS IN EUROPE RECOVERED AND BEGAN THE PRODUCTION OF MILK AND DAIRY PRODUCTS, THE DEMAND FOR DAIRY PRODUCTS FROM THE U.S. DROPPED. WITH NO SUPPORT MECHANISM, BOTH DAIRYMEN AND PROCESSORS WERE IN DANGER OF LOSING A SUBSTANTIAL SHARE OF THEIR MARKETS. THUS THE 1949 AGRICULTURAL ACT WAS ORIGINALLY A RESPONSE TO A POTENTIAL CATASTROPHE. IT WAS A PROGRAM DESIGNED TO ALLOW THE SECRETARY TO INCREASE OR REDUCE MILK PRODUCTION IN A GRADUAL WAY THAT WOULD NOT BE CATASTROPHIC TO EITHER THE DAIRY FARMER OR THE PROCESSOR.

THE ACT ALSO RECOGNIZED THE IMPORTANCE OF CHEESE, MILK AND OTHER DAIRY PRODUCTS IN THE U. S. DIET AND MOVED TO INSURE THAT CONSUMERS WOULD ALWAYS HAVE AN ADEQUATE SUPPLY.

WHILE THIS PRICE SUPPORT PROGRAM INITIATED IN 1949 WAS THE BELL COW OF THE POLICY TO DIRECTLY SUPPORT MILK PRICES TO DAIRY FARMERS, OTHER PROGRAMS HAVE SUBSEQUENTLY SUPPLEMENTED THIS ACTIVITY WITH SUBSTANTIAL IMPACT ON THE CHEESE INDUSTRY.

THE FEDERAL MILK ORDER SYSTEM ENABLED BY THE 1937 MARKETING AGREEMENTS ACT WAS AIMED AT STABILIZING MILK PRICES TO MILK PRODUCERS SUPPLYING FLUID MILK MARKETS BY A SYSTEM OF CLASSIFIED PRICING. THAT IS, REQUIRING THE PROCESSORS TO PAY FOR MILK ON THE BASIS OF HOW IT WAS USED.

AS MORE AND MORE MILK BECAME ELIGIBLE FOR FLUID USE, FEDERAL ORDERS PRICED LARGER VOLUMES OF MILK USED TO PRODUCE MANUFACTURED DAIRY PRODUCTS. TODAY WITH ABOUT 85% OF THE FLUID MILK PRODUCED ELIGIBLE FOR FLUID USE, WE ESTIMATE THAT 71% OF THE TOTAL MILK USED TO PRODUCE CHEESE IS NOW PRICED UNDER THE PROVISIONS OF A FEDERAL ORDER.

ALSO, OTHER FEDERAL PROGRAMS TENDED TO SPRING FROM THE OPERATION OF THE PRICE SUPPORT PROGRAM. IN THE EARLY 60'S A PAYMENT IN KIND PROGRAM WAS INITIATED TO ENCOURAGE THE EXPORT OF SURPLUS DAIRY PRODUCTS ACCUMULATED UNDER THE PRICE SUPPORT SYSTEM. SECTION 709 OF THE 1965 FOOD & AGRICULTURAL ACT AND SECTION 4(A) OF THE AGRICULTURAL AND CONSUMER PROTECTION ACT OF 1973 PROVIDED FOR THE PURCHASE OF DAIRY PRODUCTS AT MARKET PRICES FOR DOMESTIC SCHOOL LUNCH AND WELFARE USE. SECTION 32 OF THE AGRICULTURAL ADJUSTMENT ACT PROVIDED SIMILAR AUTHORITY.



IN RECENT YEARS SUBSTANTIAL VOLUMES OF MOZZARELLA CHEESE HAVE BEEN BOUGHT UNDER THESE ENABLING ACTS.

P.L. 480, SOMETIMES CALLED THE FOOD FOR PEACE ACT, GAVE BROAD AUTHORITY TO USE CHEESE AND DAIRY PRODUCTS FOR INTERNATIONAL RELIEF AS WELL AS TO ALLOW THE SALE OF SUCH PRODUCTS FOR FOREIGN CURRENCIES OR TO BARTER FOR PRODUCTS NEEDED BY THE UNITED STATES.

VERY LIMITED QUANTITIES OF CHEESE HAVE BEEN UTILIZED UNDER THE PROVISION OF THIS LAW. THE PRINCIPAL PRODUCT DISTRIBUTED INTERNATIONALLY HAS BEEN NONFAT DRY MILK.

ANOTHER GOVERNMENT POLICY THAT IMPACTED THE CHEESE INDUSTRY WAS THE DECISION TO USE CCC STOCKS FOR DOMESTIC RELIEF PROGRAMS. THIS NOT ONLY IMPACTED THE CHEESE INDUSTRY, BUT ALSO HAD BROAD SOCIAL IMPLICATIONS. THE AGRICULTURAL ADJUSTMENT ACT WAS THE LAW THAT IMPLEMENTED THE POLICY TO DONATE CCC SURPLUSES TO THE SCHOOL LUNCH PROGRAM AND FOR DOMESTIC WELFARE USES. FROM 1962 TO 1964 AN AVERAGE OF 137 MILLION POUNDS OF CHEESE PER YEAR WAS UTILIZED IN THESE CHANNELS. DURING THE LATE 60'S AND EARLY 70'S THE DONATIONS FELL AS COMMODITY CREDIT CORPORATION STOCKS OF CHEESE WERE UNAVAILABLE BUT PICKED UP AGAIN IN THE LATE 70'S AS COMMODITY CREDIT CORPORATION PURCHASES OF CHEESE INCREASED, AND BY 1983 MOVED TO THE CURRENT LEVEL OF SOME 40 MILLION POUNDS MONTHLY.

THE POLICY OF SUPPORTING MILK PRICES WITH NO VOLUME RESTRICTION HAS HAD A SUBSTANTIAL IMPACT ON ALL SEGMENTS OF THE CHEESE INDUSTRY. WHETHER THE IMPACT COULD BE CONSIDERED POSITIVE OR NEGATIVE DEPENDS ON THE PARTICULAR PART OF THE INDUSTRY TO WHICH YOU BELONG.

IT MIGHT BE WELL TO EXAMINE SOME OF THE IMPACTS AND THE INFLUENCE THEY HAVE HAD ON DIFFERENT SEGMENTS OF THE INDUSTRY.

LET'S FIRST EXAMINE THE IMPACT ON MILK PRODUCERS. I THINK NO ONE WOULD QUESTION BUT WHAT DAIRYMEN HAVE RECEIVED HIGHER PRICES AS A RESULT OF THE PRICE SUPPORT PROGRAM THAN THEY WOULD HAVE RECEIVED WITHOUT IT. HOW MUCH HIGHER IS DIFFICULT TO DETERMINE.

FIVE YEARS AGO THE OFFICE OF MANAGEMENT AND BUDGET COMPLETED A STUDY FOR THE DAIRY SUBCOMMITTEE OF THE AGRICULTURE COMMITTEE OF THE HOUSE OF REPRESENTATIVES. THIS STUDY POSTULATED MILK PRICES FOR THE PREVIOUS THREE YEAR PERIOD WITHOUT SUPPORTS AND COMPARED IT TO THE ACTUAL PRICES WITH THE SUPPORT PROGRAM. WITHOUT PRICE SUPPORTS THE STUDY INDICATED PRICES WOULD HAVE DROPPED PRECIPITOUSLY BUT WOULD HAVE RECOVERED TO NEARLY THE SAME LEVEL AS THAT ESTABLISHED BY THE THEN EFFECTIVE PRICE SUPPORT PROGRAM. THE REPORT THEORIZED THAT PRICE LEVELS UNDER THE PRICE SUPPORT SYSTEM WERE NOT SUBSTANTIALLY HIGHER THAN THEY WOULD HAVE BEEN IF THERE HAD BEEN A TOTALLY FREE MARKET.

IT WOULD BE DIFFICULT TO SAY WITH ANY DEGREE OF ASSURANCE THAT OVER THE PAST THREE DECADES PRICES SET BY THE PRICE SUPPORT PROGRAM WERE ONLY HIGH ENOUGH TO PROVIDE AN ADEQUATE SUPPLY OF MILK AND DAIRY PRODUCTS AND NOT SO HIGH AS TO UNDULY ENCOURAGE UNNEEDED MILK PRODUCTION. BEING SUBJECT TO POLITICAL PRESSURES PRICE SUPPORT LEVELS HAVE NOT ALWAYS BEEN SET ON THE BASIS OF PURE ECONOMICS. ON THE OTHER HAND, WITH

THE NUMBER OF FARMS REPORTING MILK COWS IN 1940 AT THE INCEPTION OF THE PRICE SUPPORT PROGRAM AT 4-1/2 MILLION VERSUS AROUND 311,000 IN 1983, ONE MUST BELIEVE THAT OVER THE LONG PULL PRICES DID NOT ATTRACT AN UNDUE AMOUNT OF RESOURCES TO MILK PRODUCTION.

HOWEVER THE ACCUMULATION OF DAIRY SURPLUSES THAT BEGAN IN THE EARLY 80'S WOULD INDICATE THAT DAIRYING AT LEAST IN RELATION TO OTHER AGRICULTURAL CROPS WAS A HIGHLY DESIRABLE ENTERPRISE. I ALSO THINK WE CAN SAFELY SAY THE RESULTING CCC EXPENDITURES ARE PROBABLY NOT POLITICALLY ACCEPTABLE NOW OR IN THE FUTURE.

ANOTHER FAVORABLE IMPACT OF THE PRICE SUPPORT PROGRAM ON DAIRYMEN WAS THE PRICE STABILITY IT PROVIDED NOT ONLY THROUGH KNOWN PRICE LEVELS, BUT THE ASSURANCE THAT THERE WAS A MARKET FOR ALL THE MILK THAT A DAIRY FARMER WANTED TO PRODUCE.

PRICES WERE ESTABLISHED BY THE SECRETARY OF AGRICULTURE BEGINNING WITH THE MARKETING YEAR. USUALLY THE MARKETING YEAR BEGAN IN APRIL, ALTHOUGH IN 1977 THE BEGINNING OF THE MARKETING YEAR WAS CHANGED TO OCTOBER. THE PRICE SUPPORT PROGRAM DICTATES THAT THE SECRETARY CAN INCREASE THE PRICE DURING A MARKETING YEAR, BUT HE IS NOT ALLOWED TO REDUCE IT. THUS, DAIRYMEN KNOW FOR AT LEAST A YEAR ABOUT THE PRICE LEVEL THEY CAN COUNT ON. ALSO, SINCE THIS PRICE LEVEL WAS, AND IS, USED IN VARYING FORMS TO SET THE BASIC FORMULA PRICE IN MOST FEDERAL ORDERS, IT PROVIDES A SIMILAR DEGREE OF STABILITY FOR FLUID MILK PRODUCERS.

THERE IS A NEGATIVE SIDE OF THE SUPPORT PROGRAM ON FARM PRICES. THE IMPLEMENTATION OF THE DECISION TO SUPPORT PRICES TO DAIRY FARMERS GAVE SOME RECOGNITION TO THE VALUE OF BUTTERFAT AND THE NONFAT PORTION OF MILK, BUT THE FEDERAL ORDER PRICING PROVISIONS HAVE TENDED TO ENCOURAGE VOLUME PRODUCTION WITH ONLY LIMITED EMPHASIS ON BUTTERFAT. THERE IS NO EMPHASIS ON THE SOLIDS NOT FAT OR PROTEIN PORTION OF MILK IN THE FEDERAL ORDER PRICING SYSTEM.

AS MORE OF THE TOTAL MILK SUPPLY IS PRICED UNDER THE PROVISIONS OF FEDERAL MILK ORDERS, AND MORE OF THE TOTAL MILK PRODUCTION IS USED TO PRODUCE CHEESE AND OTHER DAIRY PRODUCTS, IT IS OBVIOUS THAT WRONG SIGNALS HAVE BEEN SENT TO DAIRYMEN SO MOST HAVE FAILED TO ADJUST THEIR MILK PRODUCTION TO FIT THE NEEDS OF CHEESE PROCESSORS AND ULTIMATELY CONSUMERS.

CURRENTLY LESS THAN ONE-HALF OF THE TOTAL MILK SUPPLY IS BEING USED FOR FLUID USES. ABOUT 30% OF THE TOTAL IS BEING USED IN THE PRODUCTION OF CHEESE. IT IS UNFORTUNATE THAT FEDERAL ORDER PRICING DID NOT RECOGNIZE THIS TREND AND MAKE ADJUSTMENTS IN PRICING SYSTEMS THAT WOULD HAVE ENCOURAGED THE PRODUCTION OF MILK TO FIT THE PRODUCT NEEDS OF THE MARKETPLACE.

IN CONCLUSION I THINK WE CAN SAY THAT THE FARMERS HAVE ENJOYED A HIGHER PRICE UNDER THE PRICE SUPPORT PROGRAM THAN THEY WOULD HAVE HAD IF THEY WOULD HAVE BEEN IN A TOTALLY FREE MARKET. THEY HAVE ENJOYED A GREAT DEAL OF PRICE STABILITY. FOR THE MOST PART THEY HAVE NOT HAD THEIR INCOME UNDULY ENHANCED BY THE PROGRAM. THEY PROBABLY HAVE RECEIVED THE WRONG SIGNALS AS TO THE TYPE OF MILK THEY SHOULD BE PRODUCING FOR THE MARKETPLACE.

LET US NOW TURN TO THE IMPACT OF THE PRICE SUPPORT PROGRAM ON THE MANUFACTURING AND PROCESSING INDUSTRY.

POSSIBLY THE SINGLE MOST IMPORTANT IMPACT THE PRICE SUPPORT PROGRAM HAS HAD ON CHEESE MANUFACTURERS HAS BEEN THE STABILITY THAT IT HAS BROUGHT TO THE INDUSTRY. WITHOUT THE MARKET CLEARING FUNCTION THAT THE COMMODITY CREDIT CORPORATION PERFORMS THAT MINIMIZES THE IMPACT OF BOTH SEASONAL AND YEAR TO YEAR FLUCTUATIONS IN MILK PRODUCTION, CHEESE MANUFACTURERS WOULD HAVE BEEN FACED WITH A BOOM BURST ECONOMIC CYCLE THAT COULD HAVE SPELLED DISASTER FOR MANY CHEESE MANUFACTURERS AND PROCESSORS.

CHEESE, LIKE MOST OTHER DAIRY PRODUCTS, IS STORABLE ONLY FOR A LIMITED PERIOD OF TIME. THUS, IT WOULD HAVE BEEN DIFFICULT TO MAINTAIN NECESSARY INVENTORIES WHEN SHORT TERM AND RELATIVELY SMALL IMBALANCES IN SUPPLY AND DEMAND COULD RESULT IN VIOLENT PRICE FLUCTUATIONS.

THE PRICE SUPPORT PROGRAM FOR CHEESE HAS PREVENTED THESE VERY VOLATILE PRICE FLUCTUATIONS. I HAVE HEARD MANY CHEESE PROCESSORS AND MANUFACTURERS COMPLAIN ABOUT THE LEVEL OF PRICES ESTABLISHED BY THE PRICE SUPPORT PROGRAM, BUT I HAVE NEVER HEARD ONE CRITICIZE THE STABILIZING INFLUENCE OF THE PROGRAM.

ANOTHER IMPACT THE PRICE SUPPORT PROGRAM HAS HAD ON THE CHEESE INDUSTRY IS TO PROVIDE A BASIC PRICE STRUCTURE FOR ESTABLISHING PRICES TO THE RETAIL AND FOOD SERVICE TRADE AND THUS TO U.S. CONSUMERS. MOST KNOWLEDGEABLE PURCHASING AGENTS CHARGED WITH THE PROCUREMENT OF CHEESE UNDERSTAND THE PRICE SUPPORT PROGRAM AND THE PART IT PLAYS IN ESTABLISHING CHEESE PRICES. ALSO, PRICE STABILITY HAS PROBABLY BEEN GOOD FOR CHEESE CONSUMPTION. WHILE THE DEMAND FOR CHEESE IS SOMEWHAT PRICE

ELASTIC, THE BENEFITS OF PRICE STABILITY, THAT IS THE DAMPENING OF THE BOOM-BUST CYCLE THAT IS COMMON IN SOME UNSUPPORTED AGRICULTURAL PRODUCTS PROBABLY OUTWEIGHS THE BENEFITS THAT MIGHT HAVE OCCURRED FROM A SLIGHTLY LOWER AVERAGE PRICE WITH THE ATTENDANT FREQUENT PRICE CHANGES.

A POSSIBLE NEGATIVE IMPACT IN THE PRICE SUPPORT PROGRAM IS THE EQUALIZATION OF VALUES BETWEEN 100 POUNDS OF MILK USED TO PRODUCE BUTTER AND POWDER AND THE 100 POUNDS USED TO PRODUCE CHEESE. THIS EQUALIZATION HAS PROBABLY DONE A BAD JOB OF ALLOCATING MILK SUPPLIES NOT NEEDED IN THE BUTTER AND NONFAT INDUSTRY TO THE CHEESE INDUSTRY OR OTHER DAIRY PRODUCTS OR USES. WITH BETTER THAN A BILLION POUNDS OF NONFAT PRODUCED ANNUALLY AND DOMESTIC MARKET NEEDS AT ABOUT THE 300-MILLION POUND LEVEL, IT APPEARS THAT IT IS TIME TO BEGIN SOME SORT OF A REALLOCATION PROGRAM TO MOVE MILK FROM THE PRODUCTION OF BUTTER AND POWDER TO CHEESE OR OTHER DAIRY PRODUCTS. CERTAINLY THIS SHOULD BE DONE GRADUALLY SO AS TO MINIMIZE ITS FINANCIAL IMPACT ON PROCUREMENT OF NONFAT AND BUTTER AND TO ALLOW FOR THE DEVELOPMENT OF NEW CHEESE MARKETS. BUT SOMEDAY THIS ADJUSTMENT WILL HAVE TO OCCUR EITHER WITHIN OR OUTSIDE OF THE PRICE SUPPORT PROGRAM.

THERE HAVE BEEN A COUPLE OF OTHER NEGATIVE IMPACTS OF THE PRICE SUPPORT PROGRAM. THE STABILIZING INFLUENCE OF PROVIDING A MARKET CLEARING FUNCTION THROUGH THE PURCHASE OF ONE VARIETY OF CHEESE HAS PROBABLY REDUCED INNOVATIONS IN CREATING NEW CHEESE PRODUCTS AND DUPLICATING CHEESE ITEMS THAT ARE NOW IMPORTED. WITHOUT THIS MARKET CLEARING FUNCTION, THERE LIKELY WOULD HAVE BEEN SUBSTANTIALLY MORE INNOVATION IN DEVELOPING NEW

CHEESE PRODUCTS OR REPLACING CERTAIN IMPORTED CHEESE ITEMS WITH DOMESTICALLY PRODUCED PRODUCT.

ANOTHER NEGATIVE IMPACT IN THE PRICE SUPPORT PROGRAM IS ITS TENDENCY TO ENCOURAGE THE PRODUCTION OF CHEESE FOR THE COMMODITY CREDIT MARKET RATHER THAN FOR THE DOMESTIC OR CONSUMER MARKET.

IN MY JUDGEMENT, OVER THE PAST FOUR OR FIVE YEARS WE HAVE NOT PAID ENOUGH ATTENTION TO THE PRODUCTION OF PRODUCTS FOR THE CONSUMER MARKET, BUT HAVE BECOME TOO CONCERNED WITH PRODUCT YIELD, AND REDUCTIONS IN MANUFACTURING AND INGREDIENT COSTS. THE CONSUMER IS OUR ULTIMATE MARKET AND WE BEST NOT FORGET IT.

OTHER GOVERNMENT POLICIES THAT HAVE EXERTED MAJOR INFLUENCES ON THE CHEESE INDUSTRY INCLUDE THE DECISION TO LIMIT THE IMPORTATION OF FOREIGN DAIRY PRODUCTS, PRINCIPALLY CHEESE.

THE DAIRY PRICE SUPPORT PROGRAM IS USED AS THE RATIONAL FOR APPLYING IMPORTS. SECTION 22 OF THE AGRICULTURAL ADJUSTMENT ACT OF 1933 AS AMENDED FROM TIME TO TIME PROVIDES A FORUM FOR THE SECRETARY OF AGRICULTURE TO REQUEST RESTRICTIONS ON IMPORTS THAT "RENDER INEFFECTIVE OR MATERIALLY INTERFERE WITH ANY USDA SUPPORT PROGRAM." ADDITIONALLY THIS ACT CAN IMPOSE IMPORT FEES THAT WILL TEND TO RESTRICT THE DUMPING OF FOREIGN SURPLUSES OR SUBSIDIZED CHEESE AND DAIRY PRODUCTS ON U.S. MARKETS IN A MANNER THAT TENDS TO REDUCE THE DOMESTIC PRODUCTION.

FOR THE MOST PART THE POLICY OF LIMITING IMPORTS HAS A FAVORABLE IMPACT ON DAIRY FARMERS AND CHEESE MANUFACTURERS. WITH OR WITHOUT A PRICE SUPPORT PROGRAM THE FREE IMPORTATION OF SURPLUSES OF ANOTHER COUNTRY CAN DESTROY MARKETS FOR BOTH DAIRYMEN AND CHEESE MANUFACTURERS. SUCH SURPLUSES HAVE OVER THE YEARS

BEEN INTERMITTENTLY AVAILABLE. THEY APPEAR TO BE AVAILABLE ONLY WHEN THERE IS A SUBSTANTIAL SURPLUS IN AN EXPORTING COUNTRY AND WHEN THE PRICES IN THE U.S. ARE ATTRACTIVE IN RELATION TO PRICES OF THE EXPORTING COUNTRY, OR WHEN SUBSIDIES ARE AVAILABLE TO THE EXPORTING COUNTRY.

THE CURRENT POLICY ON IMPORTS MAY HAVE A NEGATIVE IMPACT ON BROKERS AND DISTRIBUTORS WHO DEAL IN THE IMPORTATION OF CHEESE AND OTHER DAIRY PRODUCTS, BUT IT IS CERTAINLY BENEFICIAL TO DAIRYMEN AND CHEESE PROCESSORS IN THE UNITED STATES.

FINALLY, LET'S DISCUSS THE POLICY ADOPTED BY THE FOOD AND DRUG ADMINISTRATION IN THE MID-60'S WHEN THEY DECIDED NOT TO PURSUE AN APPEALS COURT DECISION THAT STRUCK DOWN THE SO-CALLED FILLED MILK LAW. THE RATIONAL OF THE COURT WAS THAT THE LAWS WERE OLD FASHIONED AND FAILED TO RECOGNIZE NEW TECHNOLOGY. THE FDA'S POLICY DECISION TO ALLOW THE TERMINATION OF THIS LAW MADE PRACTICAL THE DEVELOPMENT AND SUBSEQUENT MARKETING OF IMITATION CHEESE. FOR THE MOST PART THE PRODUCT IS MADE FROM IMPORTED CASEIN AND VARIOUS KINDS OF VEGETABLE OIL. THE LATEST FIGURES I HAVE SEEN WOULD INDICATE THAT THESE IMITATION CHEESES HAVE TAKEN FROM FIVE TO SEVEN PERCENT OF THE MOZZARELLA AND AMERICAN CHEESE MARKET. THE MOST PART OF THIS PENETRATION OF THE DOMESTIC MARKET HAS RESULTED FROM SALES TO MANUFACTURERS OF FROZEN PIZZAS WHO INTEGRATE THE INGREDIENTS IN THE IMITATION CHEESE INTO THE PIZZA LABEL. LATELY, HOWEVER, SAMI AND NIELSEN DATA INDICATES A GROWING SHARE OF THE RETAIL CONSUMER MARKET FOR PROCESSED CHEESE IS BEING REPLACED BY THESE PRODUCTS.

CURRENTLY I THINK THERE ARE PROBABLY TWO LIMITING FACTORS OTHER THAN RESTRICTIVE LAWS THAT WOULD LIMIT THE GROWTH



OF THESE PRODUCTS. FIRST IS THE AVAILABILITY OF CASEIN. CASEIN IS BASICALLY A SURPLUS PRODUCT PRODUCED PRINCIPALLY IN NEW ZEALAND, AUSTRALIA AND PARTS OF THE EUROPEAN ECONOMIC COMMUNITY. IT IS THE END USE FOR MILK WITH LOW MARGINS FOR THE EXPORTER. THE SECOND LIMITING FACTOR IS THE FLAVOR SYSTEMS COMMON TO MOST OF THE IMITATION AMERICAN CHEESE THAT I HAVE TASTED. THEY ARE FAR INTERIOR TO NATURAL CHEESE FLAVORS, ALTHOUGH WHEN USED ON SOME OF THE SANDWICHES WHERE HIGHLY FLAVORED CONDIMENTS ARE ADDED, FLAVOR PROBABLY MAKES LITTLE DIFFERENCE.

BY FAR AND AWAY THE MOST LIMITING LEGAL FACTOR CAN BE THE REQUIREMENT FOR APPROPRIATE LABELING, BOTH FOR RETAIL AND FOOD SERVICE PRODUCTS. THE CONSUMING PUBLIC STILL HAS A HIGHLY NEGATIVE REACTION TO THE TERM IMITATION.

THE ADVENT OF THE IMITATION OR SUBSTITUTE CHEESE HAS PROBABLY BEEN DETRIMENTAL TO DAIRY FARMERS, BUT PROBABLY BENEFICIAL TO CERTAIN CHEESE MANUFACTURERS. CERTAINLY RETAIL OUTLETS WHO FIND IMPROVED MARGINS WHEN SELLING THE IMITATION CHEESE PRODUCTS IN RELATION TO REAL CHEESE HAVE BENEFITTED.

IN CONCLUSION, GOVERNMENT POLICIES DO IMPACT THE CHEESE INDUSTRY, ALL SEGMENTS OF IT. WE HAVE DISCUSSED A FEW OF THESE POLICIES AND HOW THEY HAVE INFLUENCED THE CHEESE INDUSTRY OVER THE YEARS. FOR THE LAST THREE YEARS ACCUMULATING SURPLUSES HAVE RAISED QUESTIONS ABOUT THE FUTURE OF THE SUPPORT PROGRAM. ALSO, THE FEDERAL MILK ORDER PROGRAM HAS COME UNDER ATTACK. THE SPIRIT OF CHANGE SEEMS TO BE IN THE AIR. WILL 1985 BRING NEW GOVERNMENT POLICIES AND IF SO, WHAT WILL BE THEIR IMPACT ON THOSE OF US IN THE CHEESE INDUSTRY?

IF THERE IS TO BE A CHANGE, BE SURE THAT YOU TAKE AN  
ACTIVE PART IN MOLDING IT. IF YOU DON'T YOU HAVE ONLY YOURSELF  
TO BLAME.

JLR:BD

7-84

BOB SHELDON  
REAL CALIFORNIA CHEESE  
MARK OF DISTINCTION PROGRAM

In 1981 California dairymen were faced with an ever growing surplus of milk (as were all U.S. dairymen). Because of their unique climatic and geographic position, California dairymen, rather than curtail production, asked their California Milk Advisory Board to develop plans to somehow increase the use of their milk.

This presentation covers the cheese part of that charge---a Real California Cheese Mark of Distinction Program. How we started, production of cheese, early results, where we are going, short term, long term. It is a step-by-step explanation of how this successful marketing plan was accomplished.

# UTAH STATE UNIVERSITY CHEESE INDUSTRY CONFERENCE

## DEVELOPMENT OF A DEFINED SINGLE STRAIN STARTER SYSTEM IN NEW ZEALAND

H.A. HEAP AND R.C. LAWRENCE

Up until 1976, the New Zealand starter system had remained much the same for 40 years, i.e., the use of a rotation of three or four pairs of phage-unrelated single strains. Pair A/B would be followed by pair C/D and then by pair E/F. The conclusion was reached, however, that rather than rotate three pairs of starter strains, it might be advantageous to use all six strains together. This defined multiple starter would then be used continuously, so that the cheesemaker would need to become familiar with the characteristics of only a single culture rather than three individual pairs. In addition, the flavor of the cheese would be more uniform since the use of different starter pairs tends to result in slightly different flavors in the mature cheese.

The multiple starter system was introduced into New Zealand cheese plants in 1976 and since then the concept has been adopted successfully also in North America and in Ireland. Multiple strains certainly perform well in small, single fill cheese plants and indeed three New Zealand plants are still using MS2 which was the first multiple introduced commercially. In all plants, however, four out of the six strains in the original MS2 were quickly attacked by fast-replicating phages. These strains were replaced one at a time, at yearly intervals, by strains that were less sensitive to phage attack to give the multiple currently being used, i.e. MS6. MS6 then only contains two of the original strains used in MS2. None of the strains in MS6 is attacked by a fast replicating phage but five of the strains are attacked by slow

replicating phages. No one phage, however, will attack more than one starter strain.

Most New Zealand cheese plants have increased considerably in throughput since 1976, and the multi-filling of vats throughout the day means that the starters now have to be more uniform in acid production. Any phages present must therefore be slow - replicating so that phage numbers do not build up significantly from one fill to the next. The phage levels that resulted with the first two commercial multiples, MS2 and MS3, were too high to enable multi-fills of vats to take place. It was decided in 1978, therefore to revert to a rotation of three pairs, A/B, C/D, E/F. Fast-replicating phages for two of the strains, D and F, soon appeared and so a further decision was taken in 1979 to use strain B on all fills. This was in line with the long held view that the fewer strains that are used in a cheese plant, the fewer phage problems will eventuate. This move proved to be successful and it only needed courage to suggest to cheesemakers in New Zealand that the two strains, A and B, should be used continuously as neither strain was attacked by phage.

This is the basis of a new concept in starter technology which has been called the "single pair" system and was first introduced in 1980. Since then most New Zealand cheese plants have been using this same single pair of strains, that is, every vat of cheese on every fill on every day has been made with the same pair A/B for at least three years, and in some cases for four years. In New Zealand a starter pair consists of one temperature-sensitive and one temperature-insensitive strain. Although a slow-replicating phage has now appeared intermittently in all cheese plants for the temperature-sensitive strain B, this has not been a sufficient problem as yet to necessitate a change

Strain Isolation Characterization

Act { Activity  
Temp sens  
Salt Sens

Flavor { Cheese making

Phage { sens. — Most Important  
UV induct  
Fat Whay  
Phage Virulence

Inhib { Antibiotic production  
Sens. to natural + added antibiotics  
Plasmid DNA Analysis

Characterized Strain

Two Years

0.2 cult

0.2 ml phage Mix

32-38C 5h

Whey - Millipore filtered

0.1ml

0.2ml  
~~Exact~~  
cult

0.1ml  
phage  
Mix

X 7 cycles

Sens

Resistance

in strain. Clearly it will be more hazardous if a phage appears for the temperature-insensitive strain A since this strain controls the rate of acid production after the curd has been "cooked". One has therefore to be in a position where the starters currently in use can be replaced when necessary. Following commercial trails, proven replacement pairs have been stored away against the time that will presumably inevitably come when the current pair has to be replaced.

The success of the "single pair" approach appears to be the result of achieving effective control against phage. To attain this control, there are four important criteria to recognize. Firstly, careful selection of the starter strains is essential. A laboratory test is used whereby development of a phage active against a newly isolated starter strain may be anticipated before the strain is released to the dairy plant. This ensures that the starter strain is not readily attacked by phages present.

Secondly, the use of a limited number of starter strains at any one time is important. This restricts the number of bacterial hosts on which the phage can replicate thereby reducing the overall phage levels in the plant.

Thirdly, eliminating the subculture of starter strains in milk by freezing and providing frozen bulk-set cultures. As many of the properties of lactic streptococci are genetically unstable, including phage sensitivity, freezing prevents cultural changes occurring.

Fourthly, experience has shown that the appearance of slow-replicating phages does not prevent the commercial use of sensitive starters, provided plant hygiene is satisfactory.

Although the present pair of strains has performed well over the past three - four years in New Zealand, there is no way of predicting how long it will be before fast-replicating phages appear that will attack both of these strains. However a recent modification to the procedure for selecting strains that are suitable back-up starters for the industry, has proved a timely breakthrough in starter technology at the New Zealand Dairy Research Institute. It is now possible to isolate more readily, bacteriophage insensitive strains that should ensure the long-term success of the single starter pair concept in New Zealand.



## Outline of Presentation

Title - "Dairy Cultures and Enzymes-Historical Development and State of the Art",  
by Alan R. Huggins, Ph.D., Senior Technical Service Specialist, Marschall  
Products Division, Miles Labs, Inc.

### I. Introduction

This paper will cover two topics including: (1) A review of progress in starter culture technology; and (2) Recent developments in enzymes for the dairy industry, focusing on accelerated cheese ripening and cloned microbial calf rennet.

### II. Starter Culture Technology

- A. Increased demand and manufacturing of cheese has led to the development of the bacteriophage problem.
- B. Approaches to minimize the phage problem.
- C. History of starter culture technology in the U.S. and worldwide trends.
- D. Culture production and bulk-starter systems.
- E. Genetic approaches to improving starters.

### III. Developments in Enzymes for the Dairy Industry

#### A. Accelerated Ripening of Cheese

- 1. Shortening the ripening time offers potential savings in cheese storage cost and more control over flavor development.
- 2. The aging of cheese involves a complex degradation of the basic components of proteins, fats and carbohydrates into numerous flavor compounds.
- 3. The promising approaches for accelerated ripening may include one or more of the following:
  - a. Elevated curing temperatures.
  - b. Addition of enzymes either directly or via microencapsulation.
  - c. Special modified or un-modified lactic cultures.

#### B. Cloned Microbial Rennin

- 1. The demand and supply economics of natural calf rennin has led enzyme suppliers to target rennin as one of the first food-industry applications of recombinant DNA technology.
- 2. Several R & D groups have reported the successful cloning and expression of cloned calf rennin.
- 3. Work is in progress to improve fermentation yields of cloned microbial rennin and continue cheesemaking trials to determine its acceptability compared to natural calf rennin.

STUDIES ON ITALIAN STARTER MEDIA\*

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\*Paper presented at 6th Biennial Cheese Industry Conference, Logan, Utah,  
August 28-30, 1984.

Introduction. Recent advances in starter media technology for mesophilic bacteria apparently have not been successfully applied commercially in the cheese industry. In view of this, a comparative evaluation of some commercially available starter media being used for mozzarella cheese manufacture was made. Comparisons were made for (a) growth-promoting ability, i.e. number of rods (Lactobacillus bugarius) and cocci (Streptococcus thermophilus) produced during recommended incubation periods (b) acid-producing activity of the rod-coccus cells generated when inoculated into milk incubated at simulated cheese making temperatures (c) stability of generated cells when stored at 2 to 5°C and (d) the effect of adding rod and/or coccus phages to the media on the growth and subsequent acid-producing activity of the rod-coccus cells. Results of these studies then were used in effort to develop improved thermophilic starter media, especially to apply the internal pH control concept.

Methods. Commercially available media were made up and pasteurized according to manufacturer's directions. Generally, this involved dissolving the powder in cold tap water and pasteurizing by heating at 85°C for 45 minutes in a dissolution apparatus. To determine plate counts, 1.0 ml samples were blended with 99 ml peptone water (0.1% w/v) in a waring blender for 2 min and serial ten fold dilutions were prepared. One tenth of a milliliter from the appropriate dilution was spread plated on LB agar (Driessen et al., 1977. Biotechnol. Bioeng. 19:821) in duplicate. Plates were incubated at 37°C for 36-48 hrs in GasPak jars (BBL). Rod and coccus colonies were counted separately from each plate, averaged, multiplied by the dilution factor and expressed as colony forming units (cfu) per ml (Willrett, 1982. Ph.D. Thesis, O.S.U.). On this LB agar medium L. bulgaricus (rods) produce large rough colonies and S. thermophilus (cocci) produce small, pinpoint colonies. Hence,

rod and coccus colonies could be easily differentiated based on this colony morphology.

Thermophilic activity. Ten milliliters of pasteurized reconstituted non-fat dry milk (11 % solids) were inoculated with 1% and 2% cultures in duplicate. The tubes were placed in a water bath at 35°C along with an uninoculated control for 60 minutes. Then the temperature was raised to 38°C for 20 min and 45°C for an additional 10 minutes. After this increase, temperature was brought down to 40°C (through normal cooling process) and held at this temperature for an additional 150 minutes to simulate cheese making temperatures. At the end of this temperature treatment, pH of the tubes was measured and the activity was calculated as follows:

$$\text{Thermophilic activity} = (\text{pH of control tube} - \text{Average pH of 1\% inoculum}) + (\text{pH of control tube} - \text{Average pH of 2\% inoculum}).$$

For microscopic observations, slides were prepared by taking one loopful of culture and smearing on an area of approximately 1 sq cm. Smear was heat fixed, stained with methylene blue and observed under oil immersion. Individual rod and coccus cells were counted in about 20 fields, averaged and expressed as rod-coccus ratio. There was no correlation between plate counts and microscopic counts.

For studies with bacteriophages, vessels containing different media were inoculated with 4.0 ml of Lactobacillus bulgaricus CR5 and 8.0 ml of Streptococcus thermophilus CR5 grown for 16-18 hours at 37°C in reconstituted, sterile nonfat dry milk (11% solids). When phages were added, the reaction vessels were simultaneously inoculated with 1.0 ml of rod phage suspension (approximate titer  $1.0 \times 10^7$  pfu/ml) and/or 1.0 ml coccus phage suspension (approximate titer  $1.5 \times 10^6$  pfu/ml). Titratable acidities, thermophilic activities and plate counts then were determined after the "break point" (pH

recommended at end of incubation) was reached in the dissolution apparatus at 42°C.

Results. Representative results from the different types of experiments are presented in Tables 1 through 7. Additional results will be presented during the oral presentation at the conference.

Table 1 shows rod and coccus counts for some commercial frozen concentrated thermophilic cultures. This was of interest to insure that reasonable numbers of the two types of bacteria were provided since these frozen cultures were being used as inoculum sources. From the table it seems that most cultures have more cocci than rods. Whether or not the differences between cultures is important in cheesemaking is not known; it likely depends on how the rods and cocci grow in whatever medium is used to prepare bulk starter.

Table 2 shows the comparative performance of 10 different rod-coccus cultures in 4 different media. Generally, Medium A was superior in performance while Medium C generated cells which were the least active in simulated cheesemaking. The reason for this seems apparent from Table 3 where plate count data are given.

A commercial cheesemaking trial was performed with three of the media shown in Tables 2 and 3. Table 4 shows the thermophilic activity data of the cells prepared in the 3 media in 3 types of milk as performed in the cheese plant. Medium C again was the least active in each case. Table 5 shows the rod-coccus ratios achieved in the three starter media as well as the ratio in the cheese made with medium B; the ratio favored the rods in culture medium B but this did not carry over into the cheese. Rods also were in the minority in cheese made with the other two starters. When the whey samples from the three cheese vats was examined for phage, coccus viruses were detected for 6 different S. thermophilus strains. No rod phages were found.

Results of testing the various thermophilic starter media for their phage inhibitory activity can be seen in Table 6. The best medium performance-wise (Tables 2, 3, 4) proved very susceptible to phage infection, while medium C was susceptible to phage inhibition only when both rod and coccus phages were present. In view of these findings it seemed desirable to develop a medium which would generate cells as active as those produced in medium A and also be immune to phage infection. An experimental medium (medium G) was developed which met these requirements. Typical results with the new medium in comparison to media C and D appear in Table 7. It may be seen that medium G is not adversely influenced when both rod and coccus phages are added. Commercial cheese trials with this medium have not yet been made.

Acknowledgment. This research was supported by a grant from Galloway West Company, Fond du Lac, Wisconsin.

Table 1. Plate counts of commercial frozen concentrates.

<u>Culture</u>	<u>CFU Per Ml</u>			<u>Percent</u>	
	<u>Rods</u> <u>(x 10<sup>8</sup>)</u>	<u>Cocci</u> <u>(x 10<sup>8</sup>)</u>	<u>Total</u> <u>(x 10<sup>8</sup>)</u>	<u>Rods</u>	<u>Cocci</u>
1	4.9	24.0	28.9	17	83
2	5.1	29.0	34.1	15	85
3	8.2	23.0	31.2	26	74
4	1.2	3.3	4.5	27	73
5	0.72	2.9	3.62	20	80
6	6.0	1.2	7.2	83	17
7	4.7	10.0	14.7	32	68
8	5.4	4.2	9.6	56	44
9	2.1	3.2	5.3	40	60
10	62.0	160.0	222.0	28	72

Table 2. Comparison of pH, titratable acidity and thermophilic activity of different commercial frozen concentrates in four different Italian bulk starter media.

Culture	pH at break point				Titratable Acidity at Break Point				Thermophilic Activity			
	A	B	C	D	A	B	C	D	A	B	C	D
1	4.88	4.64	6.28	4.75	2.70	0.72	0.88	0.76	2.36	2.82	1.40	2.28
2	4.81	4.77	5.41	4.69	2.70	0.68	1.16	0.86	2.37	2.59	0.59	2.09
3	4.87	4.76	5.90	4.51	2.70	0.62	1.06	0.94	3.39	2.22	0.90	3.14
4	4.86	4.82	4.14	4.64	2.62	0.64	0.94	1.72	4.01	3.60	3.49	3.89
5	4.73	4.79	4.29	4.71	2.72	0.70	1.50	0.84	3.30	3.01	3.03	2.69
6	4.80	4.87	4.32	4.79	2.80	0.64	1.38	0.82	3.79	3.35	2.86	3.44
7	4.72	4.86	4.25	4.66	2.74	0.70	1.48	0.90	3.69	2.62	2.88	3.01
8	4.89	4.76	4.35	4.57	2.70	0.68	1.50	0.98	3.42	3.04	2.84	3.40
9	4.90	4.81	4.39	4.80	2.76	0.66	1.50	0.82	3.40	3.17	2.94	3.04
10	4.68	4.84	4.63	4.79	2.74	0.66	1.36	0.80	2.05	2.07	1.19	1.41

Table 3. Comparison of plate counts on LB agar of different commercial frozen concentrate grown in four different Italian bulk starter media.

Culture	cfu/ml Rods ( $\times 10^8$ )				cfu/ml Cocci ( $\times 10^8$ )				Total Counts cfu/ml ( $\times 10^8$ )			
	A	B	C	D	A	B	C	D	A	B	C	D
1	0.05	1.6	$<1 \times 10^4$	0.42	10	3.1	0.079	0.18	10.05	4.7	0.079	0.60
2	0.08	0.19	0.003	0.59	24	6.4	0.044	7.8	24.08	6.59	0.047	8.39
3	0.24	0.22	0.001	1.3	22	9.2	1.0	7.3	22.24	9.42	1.001	8.60
4	0.90	1.1	1.2	1.6	16	2.0	6.4	9.4	16.90	3.1	7.6	11.0
5	0.40	0.48	1.8	0.10	24	6.1	3.1	7.1	24.40	6.58	4.9	7.2
6	2.3	3.3	3.8	1.9	16	4.0	5.5	5.6	18.3	7.3	9.3	7.5
7	3.7	2.5	3.7	2.4	15	6.3	9.6	7.5	18.7	8.8	13.3	9.9
8	1.1	3.6	3.4	1.9	27	7.8	5.0	9.9	28.1	11.4	8.4	11.8
9	0.16	0.57	2.0	0.28	28	6.8	9.8	12.0	28.16	7.37	11.8	12.28
10	0.08	0.39	0.01	0.01	7.0	0.16	3.1	5.0	7.08	0.55	3.11	5.01



Table 4. Thermophilic activity of culture 6 grown in various media at 41°C.

<u>Medium</u>	<u>Thermophilic Activity in</u>		
	<u>Raw Milk</u>	<u>Pasteurized Cheese vat milk</u>	<u>Pasteurized reconstituted nonfat milk</u>
A	1.46	2.70	2.68
B	1.45	2.87	2.96
C	0.64	1.99	2.39

Table 5. Viable rod-coccus counts made of culture 6 grown in various Italian starter media and also in one sample of finished cheese made with starter grown in medium B.

<u>Medium</u>	<u>Rods (<math>\times 10^7</math>)</u>	<u>Cocci (<math>\times 10^7</math>)</u>
A	4.5	200
B	80.0	25
C	7.5	45
Cheese from B	2.5	73

Table 6. Effect of addition of phage on acid production and cell growth in Italian bulk starter media.\*

Vessel #	Medium	Treatment	After 5 1/2 hrs of incubation				
			pH	TA	Thermophilic Activity	Plate Counts	
						Rods ( $\times 10^6$ )	Cocci ( $\times 10^8$ )
1	A, Batch 1	No phage	4.8	2.56	3.91	7.9	25
2		Rod phage	5.02	2.44	0.68	1.9	17
3		Coccus phage	5.39	2.24	1.42	9.3	0.03
4		Rod and coccus phage	5.98	1.16	0.01	$1.5 \times 10^3$	0.001
5	A, Batch 2	No phage	4.68	2.76	4.32	7.8	18
6		Coccus phage	5.39	2.24	1.49	9.1	0.0035
7	C	No phage	4.26	1.44	2.43	6.1	2.8
8		Rod phage	4.28	1.48	2.80	5.2	7.6
9		Coccus phage	4.20	1.52	2.48	7.0	4.3
10		Rod and coccus phage	4.17	1.52	1.28	5.1	7.3
11	D	No phage	4.26	1.04	3.32	7.1	4.1
12		Coccus phage	4.32	1.00	1.41	4.2	2.1

\*Medium B was not tested since it is milk-based and known not to be phage inhibitory.

Table 7. Comparison of two commercial Italian bulk starter media with experimental medium G.

Vessel Medium	Treatment	Initial		At Break			Plate Counts		Plaque forming units per ml			
		pH	TA	pH	TA	Thermophilic Activity	Rods ( $\times 10^6$ )	Cocci ( $\times 10^8$ )	Cocci		Rods	
									'0' hr	Break point	'0' hr	Break point
D	No phage	6.28	0.40	4.51	0.92	2.93	1.5	4.0	-	-	-	-
D	Rod + coccus phage	6.28	0.42	4.58	0.84	0.48	0.4	4.4	$1.4 \times 10^3$	$1.2 \times 10^8$	$1.3 \times 10^5$	$2.5 \times 10^7$
C	No phage	6.50	0.76	4.33	1.48	2.23	4.4	2.1	-	-	-	-
C	Rod + coccus phage	6.52	0.74	4.36	1.42	2.61	2.0	7.2	$1.8 \times 10^3$	<100	$8 \times 10^4$	$5.7 \times 10^5$
G	No phage	6.80	0.78	6.20*	1.16	2.58	0.15	0.55	-	-	-	-
G	Rod + coccus phage	6.79	0.88	4.88	1.66	3.34	1.4	3.9	$1.7 \times 10^3$	<100	$1.5 \times 10^5$	$4.0 \times 10^3$

\*Two hours after this sampling the pH was 4.61.

"Appl of NZ Cult  
Technol in USA."

Prod - Cultures.  
Hansel Hays + Gary Stoddard

XXII Olympiad  
Mont Clout from your  
milk

## Getting the most "clot" out of your milk

G.H. Richardson

Sixth Biennial Cheese Industry Conference

Utah State University, Logan, UT, 84322

28 August 1984

Ernstson + Brown

Dr. Frankenstein  
Dr. Jeckle

Dr. Spock

Dr. Dracula  
Blood Clots

Cal promotion  
program

Bill Holloman

J.R. Ewins

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① Dr. Reuben Hill, a Utah State University Chemist, developed the Hill Curd Tension test in the 1920's. ② Pepsin was added to milk and mixed. A knife was placed in the bottom of the beaker and the milk was allowed to clot. ③ After 30 minutes at a set temperature curd tension was measured by determining the force required to pull the knife up through the curd. Subsequently, curd tension was determined by driving a knife down into curd. Several approaches have been developed for continuous curd tension measurements. ④ One of the best is embodied in the Formagraph built by Foss Electric, Denmark (4). We have the only one of these still in the USA and have conducted considerable work with it in our laboratories. It consists of a service and a test module. ⑤ Milk substrate is tempered in 10 mL quantities, inoculated and mixed with enzyme coagulant, transferred to the test module and observed for coagulation. The forces which develop against a vertical loop, as the milk tray is moved from side to side, create drag upon the loop. Mirrors on the loop mechanism are used to reflect ⑥ strobe light flashes every six seconds onto light sensitive paper. The resultant pattern changes from a straight line to a wishbone-like curve as milk coagulum forms. Such a curve provides better estimates of cheese cutting times.

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We are examining the value of the shape of the curve drawn by such instrumentation. For example, Dr. Okigbo demonstrated that coagulation curve shape changes with variations in casein composition (6)(Table 1).

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W=Weak coagulum      N= No coagulum in 30 min.

When the major caseins decreased ( $\delta_s$  and  $\beta$ ) and the minor ones increased (gamma and lambda and ?) as the cow produced them or as proteolysis occurred, the curve narrowed and eventually became a straight line. Thus no coagulation was indicated. <sup>17</sup> If we could get some measure of the quality of the casein or the degree of proteolysis in the coagulating milk, by calculating certain parameters of the curve, it would be of more benefit to the industry. <sup>18</sup> If we could estimate some factor such as the maximum curd strength obtainable from the data developed, this could help improve quality control of milk handling and milk payment incentives. Even if these data cannot be practically applied, there appears to be other economic incentives to the use of this instrumentation. Some excellent yield studies were recently completed at the CSIRO in Highett, Australia. Southerland and Mayes (9) used the Vanderheiden instrument to objectively determine cutting time. Using 600 Kg vats, they ran several hundred trials and concluded that there was no difference in yield over a cutting strength range that varied over about 90%! They concluded that the \$16,000 instrument would only pay

for itself when milk failed to clot but it was not necessary for routine plant operations. We think this <sup>concept</sup> to be an advantage, however, since considerable savings could be generated in enzyme coagulant costs that would soon pay for such an instrument. One could simply adjust the coagulant to the objectively-derived minimum cutting strength, consistent with maximum yield. Additionally, better control over product moisture, texture, and make schedule would result. <sup>(19)</sup> Currently we are evaluating the modifications required to adapt the instrument for use in small volumes of milk in laboratories. We have obtained a very sensitive detector <sup>(20)</sup> that should allow us to develop a laboratory model of this instrument. <sup>(21)</sup> This is the Res unit of CEM now being designed for Pilot Plant 5 at

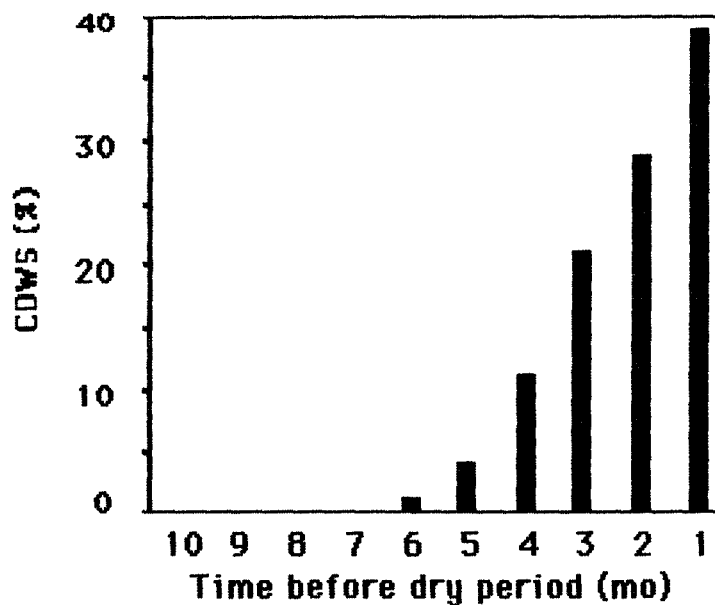
Seven prototype instruments are being assembled for evaluation <sup>OK (21)</sup> in the field. The model will be finalized depending upon the field experiences with these units. There have been numerous inquiries and most cheesemakers have demonstrated a desire to use such an instrument.

#### THE PROBLEM

<sup>(22)</sup> When Leslie Okigbo started measuring milk coagulation on the Formagraph for his Masters Degree project (5), he found more variation in milk curd strength than anticipated among animals under the same herd management. <sup>(23)</sup> In the USU Holstein herd, 38% of all animals, one month prior to their dry period, produced milk that failed to coagulate in 30 minutes (Figure 1).

Figure 1.





Fewer animals produced such milk as the distance prior to the dry period was increased. It became evident that normal milk from some animals should be used for applications where coagulation was not involved, that animals might be genetically selected for cheese manufacture, that they should be dried up earlier, or they should be shunted to make "Big Macs" instead of cheese!

#### SOLVING THE PROBLEM

We first used the method now routinely used to solve this problem; blending poor coagulating milk with good (6). We would thus expect a weaker clot but that most of the protein would be entrapped and normal cheese would result. This was not true in all cases when blends were prepared. <sup>(24)</sup> Table 2 shows the 30 minute curd strength when good coagulating milk (GCM) was mixed 50/50 with poor coagulating milk (PCM). The coagulum was poorer than expected in some cases, equal to expected in others and superior to expected in still other cases. The PCM formed a fair clot in the latter examples so the blend results

were better than when the PCM did not clot at all. The results appeared to be dependent upon the characteristics of milk from particular animals used in the blend. When PCM and GCM samples were pooled they did not coagulate in 30 minutes. Pooled GCM with 45mm strength was blended with pooled PCM with 0 strength and the result was 0 and the pH was significantly higher.

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We investigated the various parameters that might allow us to improve the clotting process in the cheese plant. When used alone, addition of calcium chloride, adjustment of pH, or modification of rennet concentrations were found to be of little value. However, when the milk pH was dropped to 6.4 by the addition of lactic acid, rennet addition was reduced to 50% of normal, and 0.02% calcium chloride was added, the rate of increase of curd firmness was improved substantially. <sup>(25)</sup> In one example the curd strength of PCM went from 16.9 to 19.5mm upon pH adjustment, to 21mm when  $\text{CaCl}_2$  was added, to 31.6mm when rennet was reduced. It was most interesting that increasing rennet did not increase curd strength as we have routinely thought. When curd was made from such adjusted milk in the laboratory, the yields were only 65% of GCM, the moisture of the curd was 60% compared to 41% for GCM, and the curd quality was very poor quality. ~~(25)~~

#### EFFECT OF MILK STORAGE

As previously mentioned, poor coagulating milk has significantly different ratios of caseins than GCM (Table 1). The poor quality caseins increase during milk storage (1). This adversely affects cheese yield. In order to minimize losses of curd forming properties during the time milk is collected and coagulated, it is suggested that every effort be made to minimize protease (plasmin) and psychrotrophic bacterial activity in milk. This can be done by storing milk at lowest possible temperatures for the shortest times before coagulation. In one study by Dr. Okigbo (6), mixtures of GCM and PCM dropped from 40.5 to 30.4

to 28.6mm curd strength during 4C storage at 0, 48 and 72 hours, respectively. Samples of PCM dropped from 16.5 to 5.25mm, for a 68% loss in curd strength during storage at -1C for 30 days. Samples of GCM during the same conditions lost 8% as curd strength dropped from 55.5 to 51.25mm.

## CONCLUSIONS

In order to maximize the clotting of milk for cheese manufacture we should test every animal, especially during late lactation, to see if she produces noncoagulating milk. Such milk should be shunted from the manufacture of cheese. Animals which display this trait persistently might have genetic properties that should be considered in selection and breeding. Lactation periods should be shortened on animals producing high levels of plasmin or protease activity. When milk is pooled it should be stored cold and processed with a minimum of delay. There are significant modifications that can be made in the Cheddar cheese process that will assure better coagulation characteristics. These include addition of calcium chloride, reduction of the pH to 6.4 prior to renneting, through lactic acid production or addition, and reducing the amount of coagulant. The latter would best be done by objective measurements of curd formation rates using the type instrumentation described earlier. We should strive to both get the best clot out of the milk and get the worst animals out of the milk supply.

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# **Getting the most "clot" out of your milk**

**G.H. Richardson**

**Sixth Biennial Cheese Industry Conference**

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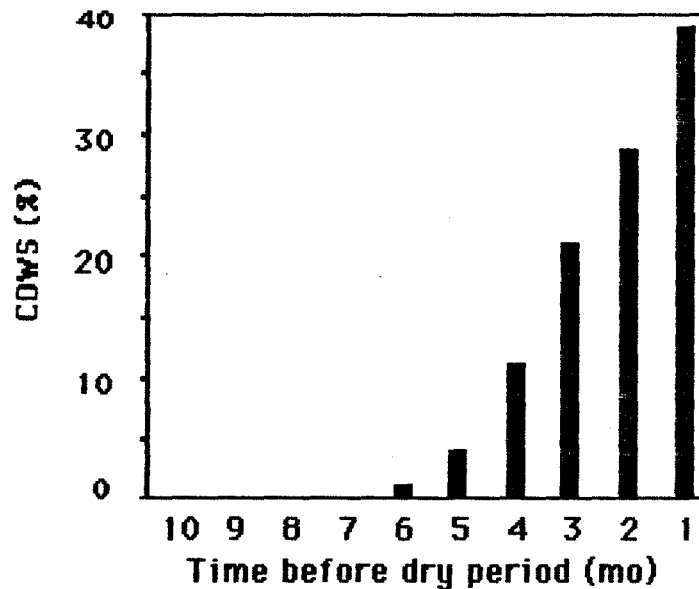
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Presented by David M. Barbano, Assistant Professor, Cornell University, Ithaca, NY, at the 6th Biennial Cheese Industry Conference held on August 28-30, 1984, at Utah State University, Logan, Utah.

MOZZARELLA CHEESE COMPOSITION, YIELD,  
AND HOW COMPOSITION CONTROL INFLUENCES PROFITABILITY

By David M. Barbano

ABSTRACT

The federal standard of identity for low moisture part skim mozzarella cheese allows a range of product moisture from 45% to 52% and fat on a dry basis (FDB) from 30% to 45%. The functional characteristics of mozzarella cheese made at the extremes of these composition ranges are very different. In addition, the profitability of manufacturing cheese at different moistures and fat on a dry basis can be very different. In this investigation we first look at the impact of manufacturing low moisture part skim mozzarella at various FDB levels without changing cheese moisture. The examples given in this paper indicate that it is more profitable for the cheese manufacture to produce higher FDB cheeses within the low moisture part skim mozzarella cheese category, mainly because of the much higher cheese yields obtained at higher FDB. Simple examples of calculations are given which would allow you to substitute in various values for cheese and fat in the cream to do an evaluation that would be more specific for your particular cheese plant. Also, the importance of composition control in maximizing profitability is demonstrated. Casein to fat ratio as a basis of milk standardization would be much better for maintaining composition control at a point that maximizes profitability of the cheese manufacturer.

I. Introduction.

The production of mozzarella cheese for the U.S. market has grown very rapidly over the past two decades. The increase in popularity of pizza has been one of the major factors contributing to the tremendous increase in demand for mozzarella cheese. A very large percentage of the utilization of mozzarella cheese is institutional use primarily in pizza parlors. Several chains of commercial pizza shops represent very large commercial accounts that purchase major quantities of cheese all year long on a contract basis. These chains of pizza parlors strive for consistency in flavor, quality, and appearance of their product offerings. Therefore, the buyers for these large accounts exert a tremendous amount of pressure on the manufacturers of mozzarella cheese to produce a mozzarella cheese that consistently meets their product composition and functionality specifications.

It is very important for both the buyer and the seller of mozzarella cheese to have clear and well defined specifications for product composition

and functionality. Once these specifications are clearly defined, it becomes a challenge for the cheese manufacturer to consistently produce cheese that is within the customer's quality specifications. An additional challenge to the cheese manufacturer is to meet the customer's product specifications at a manufacturing cost that is competitive with other cheese manufacturers and at the same time return a reasonable profit to the cheese company.

To achieve the goals of: a) consistently satisfying the customer, b) being price competitive in the market place, and c) making a profit that will sustain the company, it is necessary to have a good management team that can take advantage of new technology and at the same time execute the cheese manufacturing process to obtain consistency, quality, and profitability.

## II. Mozzarella Cheese Composition

The federal standards of identity for mozzarella cheese sets a classification system that distinguishes several different types of mozzarella cheese based on the ingredients from which they are manufactured, and most importantly, their finished product composition. The federal composition standards for mozzarella cheese are listed below.

<u>Type of Mozzarella</u>	<u>Moisture</u>	<u>Fat on a Dry Basis (FDB)</u>
Mozzarella	greater than 52% less than 60%.	not less than 45%
Low-Moisture Mozzarella	greater than 45% less than 52%	not less than 45%
Part Skim Mozzarella	greater than 52% less than 60%	not less than 30% not greater than 45%
Low-Moisture Part Skim Mozzarella	greater than 45% less than 52%	not less than 30% not greater than 45%

Using low-moisture part skim mozzarella cheese as an example, it can easily be seen that there is a very wide range of product compositions with respect to fat and moisture that all fall into the category of low moisture part skim mozzarella cheese as defined by the federal standards of identity. However, as experienced cheese manufacturers, you know that a low-moisture part skim mozzarella cheese with 47% moisture and 44% FDB is a very different product than a low-moisture part skim mozzarella with a 51% moisture and a 32% FDB. Functionally these two products would perform very differently depending on their intended use.

Because of this wide latitude within the product category of low-moisture part skim mozzarella cheese, it becomes necessary for the cheese manufacturer and the cheese buyer to work together to identify a narrower range of product composition that yields a cheese that has the functional characteristics that will satisfy the customer's needs. This is generally how business is done with large institutional buyers of low-moisture part skim mozzarella.



However, in the retail supermarket sales area there is no clear communication of the customer's needs directly to the cheese manufacturer. Therefore, it is interesting to note the diversity of cheese composition that appears in the supermarket all identified to the consumer as low-moisture part skim mozzarella. The data shown in the next table indicates the compositional differences between different brands of low-moisture part skim mozzarella cheese purchased in supermarkets in New York and Wisconsin.

Composition of Low-Moisture Part Skim Mozzarella Cheese from Retail Supermarkets in New York and Wisconsin

<u>Source</u>	<u>Moisture</u>	<u>FDB</u>	<u>Protein</u>	<u>Salt</u>
NY - 1	49.8	41.4	24.3	1.34
2	47.1	33.9	29.7	1.61
3	49.6	36.0	26.7	1.12
4	49.3	42.4	23.8	1.07
5	54.7	37.5	22.5	2.33
6	53.1	34.6	24.0	2.09
7	49.8	35.8	26.4	1.69
8	47.8	44.8	23.4	-----
9	50.2	35.4	25.5	1.91
10	49.9	35.9	26.2	1.31
11	48.5	41.8	24.0	1.07
12	52.0	40.7	22.8	2.50
13	50.0	35.0	26.2	1.90
14	44.4	48.1	24.1	.98
15	46.1	33.7	29.9	1.80
16	46.6	39.3	26.2	1.10
17	54.1	40.3	20.9	2.24
18	49.0	32.3	28.1	2.29
19	46.3	44.7	24.7	1.33
20	45.5	36.7	28.5	1.80
21	45.8	44.3	24.5	.80
22	55.4	40.9	21.4	1.82
23	47.2	33.1	29.6	1.23
Ave. NY	49.2	38.6	25.4	1.60
WI - 1	46.0	39.8	26.5	1.76
2	45.3	40.0	26.7	2.06
3	45.0	34.3	30.0	1.39
4	46.6	35.8	27.5	1.44
5	50.9	37.2	25.3	1.42
6	45.1	35.3	30.0	1.88
7	49.7	33.8	27.6	.98
8	50.3	30.7	28.7	1.77
9	46.0	40.7	26.6	1.35
10	46.3	41.9	25.2	2.33
11	47.1	31.4	29.4	2.60
Ave. WI	47.1	36.5	27.6	1.72

### III. Mozzarella Cheese Yield

Most of the research on cheese yield has been done on Cheddar cheese. Very little published information is available on mozzarella cheese yields or on theoretical cheese yield formulas for mozzarella cheese. To evaluate cheese yield performance in a mozzarella cheese plant, we need a formula for predicting cheese yield based on milk composition.

Some modifications of the VanSlyke cheese yield formula makes it acceptable for use with mozzarella cheese. A modified formula for low-moisture part skim mozzarella cheese is shown below.

$$\text{cheese yield} = \frac{[(\%FR) (F) + (C - 0.1)] 1.13}{1 - W}$$

Where

%FR = expected fat recovery in the cheese

F = fat content of milk in vat

C = casein content of milk in vat

W = % moisture in the cheese divided by 100

The %FR has been substituted for the traditional .93 that is normally used for Cheddar cheese. This number will be different depending whether you are making cheese at the high FDB or low FDB end of the wide range of acceptable FDB's for low-moisture part skim mozzarella cheese. For a cheese in the middle of the FDB range (i.e. 37.5) an 85% fat recovery may be a good target to be used in the theoretical yield formula.

The other change in the formula is the use of a constant factor of 1.13 instead of 1.09, which is used for Cheddar cheese. This factor is used to take into account the contribution of added salt and non-fat, non-protein, milk solids that contribute to cheese yield. How did I arrive at a 1.13 factor for low-moisture part skim mozzarella cheese? The data shown for the composition of mozzarella cheese on the previous page was used to determine an average factor for all the cheeses analyzed. This was done by determining the amount of non-fat, non-protein, non-salt solids present in each of the cheeses. This amount of other solids (minerals, acids, carbohydrates) plus a fixed target value of 1.7% added salt was used to calculate the constant factor of each of the cheeses. The average value was 1.13.

Therefore, the equation given at the top of this page can be used to evaluate the differences in cheese yield that will result from differences in milk composition.

#### IV. Selection of Specifications for Cheese Composition

Selection of specifications for cheese composition has to take into account the customer's needs for cheese functionality and characteristics plus the cheese manufacturer's needs to be able to manufacture, package, and market the product at a profit.

One question all mozzarella cheese manufacturers should consider is "Are there any differences in profitability of manufacture of low-moisture part skim mozzarella cheeses of different composition?" To answer this question, we need to evaluate the yields of low-moisture part skim mozzarella of different compositions.

The following group of 3 examples will compare the profitability of making three low-moisture part skim mozzarella cheeses at different fat on a dry basis (FDB). All of the following examples will start with exactly the same composition original 100 lbs of whole milk. Each example will standardize the same whole milk by partial removal of fat by separation. The moisture content will be kept at 49% and the salt content at 1.7% for all cheeses. The price of cheese will be set at \$1.31 per pound, the value of fresh cream at \$1.80 per pound of fat, and whey cream at \$1.60 per pound of fat for all the examples. The calculations are shown so that you can substitute different numbers and recalculate the examples for your own use.

##### Example 1. - milk standardized to 1.5% fat.

Start with 100 lbs of milk with 3.50% fat, 3.20% protein, and 2.43% casein. Remove 40% fat cream with a separator to obtain milk at 1.5% fat. The table below shows the composition of the original milk and the resulting cream and 1.5% fat milk. In addition it shows the pounds of cream separated and the remaining pounds of milk for cheese making.

	Weight pounds	Fat %	Fat lbs	Protein %	Protein lbs	Casein %	Casein lbs
Stand'zed milk	94.80	1.5	1.42	3.27	3.10	2.48	2.35
Fresh Cream	5.20	40.0	2.08	1.92	.10	1.46	.07
Total Milk	100.00		3.50		3.20		2.43

Cheese yield from 94.80 lbs of standardized milk

$$\frac{[.85(1.5) + (2.48 - 0.1)] 1.13}{1 - (49/100)} = 8.098 \text{ lbs cheese/cwt}$$

$$8.098 \text{ lbs} \times (94.8/100) = 7.677 \text{ lbs cheese from the 94.8 lbs of standardized milk}$$

# Cheese Composition

Moisture - 49.00%  
 FDB - 30.87% (calculated from the lbs of fat retained)  
 Salt - 1.70%

Value of cheese and cream from the original 100 lbs of milk

Cheese - 7.677 lbs x \$1.31/lb = \$10.056

Cream - (5.20 x .40) x \$1.80/lb of fat = \$ 3.744

Whey

Cream - .213 lbs fat x \$1.60/lb of fat = \$ .341

---

Total Dollars Returned from 100 lbs of milk = \$14.141

Example 2. - milk standardized to 2.0% fat.

Start with 100 lbs of milk with 3.5% fat, 3.20% protein, and 2.43% casein as in example 1 except we will skim the milk to a 2.0% fat test instead of 1.5%.

	Weight pounds	Fat %	Fat lbs	Protein %	Protein lbs	Casein %	Casein lbs
Stand'zed milk	96.05	2.0	1.92	3.25	3.12	2.47	2.37
Fresh cream	3.95	40.0	1.58	1.92	.08	1.47	.06
Total milk	100.00		3.50		3.20		2.43

Cheese yield from 96.05 lbs of standardized milk

$$\frac{[.85(2.0) + (2.47 - 0.1)] 1.13}{1 - (49/100)} = 9.018 \text{ lbs cheese/cwt}$$

$$9.018 \text{ lbs} \times (96.05/100) = 8.662 \text{ lbs cheese from the 96.05 lbs of standardized milk.}$$

# Cheese Composition

Moisture - 49.00%  
 FDB - 36.96%  
 Salt - 1.70%

Value of cheese and cream from the original 100 lbs of milk.

Cheese	-	8.662 lbs	x	\$1.31/lb	=	\$11.347
Cream	-	(3.95 x .40)	x	\$1.80/lb of fat	=	\$ 2.844
Whey						
Cream	-	0.288 lbs fat	x	\$1.60/lb of fat	=	\$ .461
Total Dollars Returned from 100 lbs of milk					=	\$14.652

Example 3. - milk standardized to 2.5% fat

Start with 100 lbs of milk with 3.5% fat, 3.20% protein, and 2.43% casein.

	Weight pounds	Fat %	Fat lbs	Protein %	Protein lbs	Casein %	Casein lbs
Stand'zed milk	97.32	2.50	2.43	3.24	3.15	2.46	2.39
Fresh cream	2.68	40.00	1.07	1.92	.05	1.46	.04
Total milk	100.00		3.50		3.20		2.43

Cheese yield from 97.32 lbs of 2.5% milk - because of the higher fat content of the milk there may be more loss of fat into the whey, thus we will reduce the theoretical fat recovery in the yield potential formula from .85 to .825 for the 2.5% milk.

$$\frac{[.825(2.5) + (2.46 - 0.1)] \quad 1.13}{1 - (49/100)} = 9.799 \text{ lbs cheese/cwt}$$

$$9.799 \text{ lbs} \times (97.32/100) = 9.536 \text{ lbs cheese from the 97.32 lbs of standardized milk.}$$

#### Cheese Composition

Moisture	-	49.00%
FDB	-	41.27%
Salt	-	1.70%

Value of cheese plus cream from the original 100 lbs of milk.

Cheese	-	9.536 lbs	x	\$1.31/lb	=	\$12.492
Cream	-	(2.675 x .40)	x	\$1.80/lb of fat	=	\$ 1.926
Whey						
Cream	-	.3705 lbs fat	x	\$1.60/lb of fat	=	\$ .593
Total Dollars Returned from 100 lbs of milk					=	\$15.011

## SUMMARY

The yield of low moisture part skim mozzarella cheese changes significantly as you increase the fat content of the standardized milk used to make this product. The calculations are based on theoretical yields which assume fat recovery in the cheese of 85% for milks at 1.5% and 2.0% fat and 82.5% for milk with 2.5% fat. Both the casein and fat content of the milk will influence the cheese yield. Notice the fact that the casein content of standardized milk will be greater than the original whole milk. For example, two milks with the same fat content but different casein content will give different yeilds and different finished product FDB.

The FDB of cheese found in the retail market place varies considerably. Commercial samples of low moisture part skim mozzarella ranged in FDB from 30.7% to 44.7%. These same cheese samples ranged from 44.4% to 54.1% moisture. Both moisture content and fat content of cheese will influence the cheese yield and total dollar return from a milk supply. The proper balance of fat and moisture content in the finished product will influence the physical characteristics and flavor. The total dollar return on a starting milk of constant composition will be greater when making cheese from a standardized milk with a higher fat content. This is true because at current prices the fat is worth much more as cheese than fresh cream.

As summarized in the table on the next page, the total income from the same 100 lbs of milk would be \$0.87 more per hundred weight with the milk standardized to 2.5% fat versus the milk standardized to 1.5% fat if the moisture content of the finished products are all 49%.

**THE KEY FACTOR IS THE QUALITY AND SUITABILITY OF THE CHEESE FOR YOUR CUSTOMER!!**

Cheese made from the higher fat milk will have a higher fat on a dry basis and this will influence its physical properties. At current cheese and cream prices it appears that by selling a product that has the highest FDB that your customer will accept, the cheese maker will maximize his return per 100 lbs of milk, if the moisture content of the cheese is held constant. It appears that it may be profitable for a company to look for customers that can use low-moisture part skim mozzarella at the high end of the FDB range. These calculations are intended as an example and you should substitute your own numbers for all parameters to obtain information that applies to your specific situation.

	Fat in Stand'zed Milk	Total Value of Cream + Cheese	Cheese Moisture	Cheese FDB
EXAMPLE 1	1.5%	\$14.14	49.00%	30.9%
EXAMPLE 2	2.0%	\$14.65	49.00%	37.0%
EXAMPLE 3	2.5%	\$15.01	49.00%	41.3%

## V. How Does Variability of Cheese Composition Influence Profitability?

Generally, large volume purchasers of low-moisture part skim mozzarella cheese will give the cheese manufacturer product specifications for cheese composition and functionality. Usually these will be specified as acceptable composition ranges for moisture, FDB, salt, and pH. In addition, the customer may have specifications for color, stretch, melt, burning, and fat release.

Moisture and FDB will both have very significant impacts on cheese yield, so let's focus on these characteristics of low-moisture part skim mozzarella cheese. Assume that your customer has given you an acceptable range of moisture of 47.5% to 50.0% and FDB of 35 to 39%. The high end of both the moisture and FDB ranges will give you the highest product yields and maximum profitability. The difficulty is that if you set your production targets at 50.0% moisture and 39% FDB, you will have many vats of cheese that exceed the maximum moisture, FDB, or both and these lots of cheese will be unacceptable to your customer. Therefore, it seems to be common practice to target the middle of the customer's specification range so that the number of lots of cheese outside the acceptable composition range is minimized. The key factor is vat to vat variation in product composition. The more vat to vat variation you have in moisture and fat content, the closer you need to stay to the middle of the specification range with your manufacturing composition targets.

The key to improving profitability is to reduce the vat to vat variation in cheese composition so that your target values can be moved closer to the most profitable cheese composition. The key point is ! FIRST ! reduce the vat to vat variation (usually measured statistically by standard deviation) and then move your target composition closer to the more profitable end of the compositional range. If you do not reduce your vat to vat variability first, you are likely to produce too much cheese that is outside of your customer's specifications and you may risk losing that customer.

How do you improve vat to vat consistency in cheese composition? Consistent cheese making conditions is the first step. Times, coagulants, temperatures, starter culture activity, salting, and cooling are some of the process parameters that need to be defined and executed consistently every day. Many cheese plants do a very good job in this area, yet their cheese composition still varies more than they would like it to.

The next factor to consider controlling is the milk composition from which the cheese is made. You will probably respond to that suggestion by saying that you standardize to the same fat test day after day so you have consistency in milk composition. The consistency in milk composition that I am referring to is in the casein to fat ratio in the milk for cheese manufacture. Additionally it really comes down to the casein to fat ratio of all the ingredients once the cheese vat is full.

Variation in the milk casein to fat ratio will cause variation in both the FDB and the moisture content of the low-moisture part skim mozzarella cheese. Because of differences in specific processing conditions in different cheese plants it is not possible for me to give you specific casein to fat ratios that will result in these specific moistures and FDB's in all cheese factories. Standardizing to a consistent casein to fat ratio by separation of

cream from whole milk does not require any additional manufacturing equipment, it just means that you need to determine milk casein content and adjust your fat removal by separation to maintain a constant ratio of casein to fat instead of a constant fat test.

Next, I will give a series of examples that will illustrate the economic value of this approach to controlling cheese composition. Let's assume that we have a customer that has product specifications for moisture content of cheese from 47.5 to 50% and FDB from 35 to 39%. What would be the difference in total end product value if we made cheese at the low end of the ranges, the middle of the ranges, and the high end of the ranges? The information is summarized below.

#### Cheese Composition

Low end of composition range - 47.5% moisture, 35% FDB.  
 Middle of composition range - 48.75% moisture, 37% FDB  
 High end of composition range - 50.0% moisture, 39% FDB.

Assume that all cheese making starts from the same 500,000 lbs of whole milk at 3.50% fat, 3.20% protein, and 2.43% casein. All equipment required for manufacturing the cheese is the same for all product compositions indicated in this example. Cheese price \$1.31 per pound, fresh cream \$1.80 and whey cream \$1.60 per pound of fat. The dollar values of each product have been calculated and are shown below.

Cheese Composition Range	Dollar Value Of			
	Cheese	Fresh Cream	Whey Cream	Total
Low End	52,900	15,750	1,500	\$70,200
Middle	56,550	14,175	1,775	\$72,500
High End	60,200	12,600	2,000	\$74,800

Assume that we target the middle of the composition range and obtain that composition. After looking at the values in the table above we can see that there is more profit at the high end of the composition range. However, our vat to vat variation in cheese composition is large enough that if we targeted half way between the middle and the high end of the composition range we would have too many vats of cheese outside the upper range limits and would risk losing a very good institutional customer.

If we could move our target to half way between the middle and high end of the cheese composition range without having an excessive amount of cheese over the upper limits for moisture and FDB, it would be worth about \$1150.00 per day (\$74,800 - \$72,500 divided by 2) on a whole milk volume of 500,000 lbs of milk per day. If standardizing to a casein to fat ratio instead of a constant milk fat percentage would help us achieve this goal, then it is just



a matter of comparing the cost of this approach to milk standardization for low-moisture part skim mozzarella cheese manufacture to the possible long term benefit in improved profitability.

The calculations of yield and dollar value of low-moisture part skim mozzarella cheese at the low and high end of the composition range for the preceding discussion are shown below.

Calculation 1 - Cheese at the low end of the composition range.

Start with 100 lbs of milk with 3.5% fat, 3.20% protein, and 2.43% casein. Remove 40% fat fresh cream with a cream separator to obtain a standardized milk that will yield a finished cheese with 47.5% moisture and 35% FDB.

	Weight Pounds	Fat %	Fat lbs.	Casein %	Casein lbs
Stand'zed Milk	95.63	1.83	1.75	2.47	2.364
Fresh Cream	4.37	40.0	1.75	1.51	.066
Total Milk	100.00		3.50		2.43

Cheese yield from 95.63 lbs of standardized milk from above:

$$\frac{[.85(1.83) + (2.47 - 0.1)] 1.13}{1 - (47.5/100)} = 8.449 \text{ lbs cheese/cwt}$$

$$9.018 \text{ lbs} \times (95.63/100) = 8.0799 \text{ lbs cheese from the } 95.63 \text{ lbs of standardized milk}$$

Cheese Composition  
Moisture - 47.50%  
FDB - 35.07%

Total Product Value with Cheese made at composition listed above.

		Per CWT Of Whole Milk	For 5000 CWT's
Cheese	8.0799 lbs/cwt x \$1.31 =	\$10.58	\$52,900
Fresh Cream	1.748 lbs fat x \$1.80 =	3.15	15,750
Whey Cream	.1945 lbs fat x \$1.60 =	.31	1,550
TOTAL PRODUCT VALUE		\$14.04	\$70,200

Calculation 2 - Cheese at the high end of the composition range

Start with 100 lbs of milk with 3.5% fat, 3.20% protein, and 2.43% casein. Remove 40% fat fresh cream with a cream separator to obtain a standardized milk that will yield a finished cheese with 50.0% moisture and 39% FDB.

	Weight Pounds	Fat %	Fat lbs	Casein %	Casein lbs
Stand'zed Milk	96.50	2.18	2.10	2.46	2.377
Fresh Cream	3.50	40.0	1.40	1.51	.053
Total Milk	100.00		3.50		2.43

Cheese yield from 96.50 lbs of standardized milk from above:

$$\frac{[.85(2.18) + (2.46 - 0.1)] 1.13}{1 - (50.0/100)} = 9.5214 \text{ lbs cheese/cwt}$$

$$9.5214 \text{ lbs} \times (96.50/100) = 9.1882 \text{ lbs cheese from the 96.50 lbs of standardized milk.}$$

Cheese Composition

Moisture - 50.00%  
FDB - 38.92%

Total product value with cheese made at composition listed above.

		Per CWT of Whole Milk	For 5000 CWT's
Cheese	9.1882 lbs/cwt x \$1.31 =	\$12.04	\$60,200
Fresh Cream	1.400 lbs fat x \$1.80 =	2.52	12,600
Whey Cream	.2507 lbs fat x \$1.60 =	.40	2,000
TOTAL PRODUCT VALUE		\$14.96	\$74,800

INNOVATION  
(Which Is Presumed)

WITHIN FEDERAL CHEESE REGULATIONS  
(Which Are Subsumed)

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August 29, 1984  
9:10 a.m.

INNOVATION WITHIN FEDERAL CHEESE REGULATIONS

By  
Merrill S. Thompson

OUTLINE

- I. Introduction.
- II. Outline of Federal Regulations.
- III. The FDA's Role vis-a-vis Innovation.  
(Prior FDA Approval versus Responsible Self-Determination.)
- IV. Historical Precedent.
  - New and Improved Varieties.
  - New and Improved Procedures.
  - New and Improved Ingredients.
- V. The Beginning and End of Cheesemaking.
- VI. A Hypothetical Defense of Ultrafiltration.
- VII. Summary.

INNOVATION  
WITHIN FEDERAL CHEESE REGULATIONS

1. The differences between 1948 and now in cheese plants, and how did we manage to do it.

2. New Varieties:

New standard.  
Old generic standard.  
Common law standard.  
No standard.  
Sui generis; substitute; imitation.

3. Improved Varieties:

Varieties within variety.  
Inherent.  
Designed.

4. New Ingredients:

Food additive status.  
Temporary permits.  
Amendments to standards.  
Common law standard.  
Safe and suitable.  
No standard.  
Sui generis; substitute; imitation.

5. Improved Ingredients:

Variable forms and specifications.  
Safe and suitable.

6. New Procedures:

New, alternate ways to make essentially the same thing.  
  
Okay under standards with "alternate make" provisions.  
Temporary permit.  
Amend standard.  
No standard.  
Substitute; imitation.

7. Improved Procedures:

A better way to do essentially the same thing to  
essentially the same things.  
No change in status under any standard.

8. Cheesemaking Procedures:

Where do they begin?  
Where do they end?

9. Administrative Procedures Applicable To Innovation:

Federal.  
FDA standards.  
Food Additive Regulations.  
Incidental Additives.  
States' impact on federal.  
Options and risks.

10. Informal Investigational (Experimental) Procedures and Options:

Intrastate commerce.  
Laboratory.  
Plant location.  
Unilateral (self-) determination.

11. Conclusion (if any there be).

ADVANCES IN THE GENETIC ENGINEERING OF CHYMOSIN (RENNIN)

H. Robert Goltz  
The Dow Chemical Company



A number of exciting and interesting developments have occurred in the past few years in the field of biotechnology. For our purposes today, biotechnology encompasses the areas of molecular biology, fermentation, and protein biochemistry. At the risk of having some of you leave us today wondering what the heck this guy was talking about, I feel that I must digress for a few moments. The central dogma of biochemistry is that DNA is transcribed to RNA which is translated to protein. (slide) DNA as a polymer, encodes the structural information for proteins in the sequence of its base units. A giant step forward in our understanding of biochemistry has come from restriction endonucleases (slide) which recognize specific sequences of DNA and cleave it at these sites. Thus segments of DNA can be cut and joined back together in different orders (using ligases). Scientists now have the ability to identify and isolate specific genetic elements (slide) and move them from one organism to another. The first generation application of this information is the ability to produce proteins in organisms such as bacteria that are easily grown in large quantities. Thus proteins can be produced that may have never been available by any other method. This means of protein production is potentially more economical than production from a traditional source.

Dr. Ernstrom invited me to talk to you today about the application of these new developments in biotechnology to the cheese industry and particularly chymosin. The long term goal of the Dow Chemical Company has been the development of an economical system for the production of genetically engineered chymosin.

Chymosin or rennin is the acid protease obtained from calf stomachs used in the milk coagulation step of cheese production. While cheese consumption has been increasing by 60 % in the United States from 1969 to 1977, the supply of chymosin has increased only 30 % over that same period. Thus chymosin substitutes such as microbial rennets and pepsin blends have made significant inroads to the marketplace. We understand many cheesemakers prefer calf chymosin as a coagulant because of its high specificity for kappa-casein and low nonspecific proteolytic activity, its sensitivity to heat inactivation and higher cheese yields of as much as 1.5 %. Thus chymosin, with a substantial market in the U.S. and Western Europe, has made an interesting target for genetic engineering as evidenced by the number of groups that have cloned the gene. By my last count there were 19 different companies or research groups that are working on the gene which is by no means unusual for this business. The work I will be describing today was conducted by The Dow Chemical Company or by Collaborative Research Inc. under contract by Dow.

The first task before us was the isolation and identification of the DNA for chymosin, accomplished by Collaborative Research. A copy of the gene was obtained by reverse transcription of messenger RNA isolated from calf stomach. Because the gene was obtained by reverse transcription of messenger RNA, the newly created DNA is a new composition of matter and patentable. Patents for the gene were issued to Collaborative Research Inc. for the United Kingdom on August 30, 1984 (Patent # 2091271B) and are presently under examination elsewhere.

Analysis of the DNA shows that the protein is synthesized as a preprochymosin, containing a hydrophobic secretion sequence at the amino terminus, functioning in the natural secretion of prochymosin as the inactive zymogen form of chymosin from the calf stomach tissue.

The protein could be engineered as either preprochymosin, prochymosin or chymosin in the organism of choice by cloning different portions of the DNA. From experiments with these different forms of the protein, workers have found that preprochymosin is apparently less stable and more difficult to activate than the other forms of the molecule. Since prochymosin exhibits a broader pH stability range than chymosin and can be readily activated to chymosin by low pH incubation, major attention has been centered on prochymosin.

The detection and optimization of a foreign gene product such as chymosin requires a series of new analytical methods for the protein. The chymosin DNA must be somehow inserted into the cell of the host organism which is usually accomplished using a plasmid-- an independently replicating, nonchromosomal piece of DNA. Since the frequency of insertion of the correct form of the DNA into the cell is low, thousands of cells may have to be screened. Growing each culture to volumes sufficient for milk clotting assays would become impossible. The assay that has been implemented for detection of chymosin producing cells is called a plate screening radioimmunoassay. (slide) The assay takes advantage of the specificity of the interaction of an antibody with the sensitivity imparted by a radioisotope. The assay involves (slide) replica plating and growing the cells overnight on nitrocellulose paper, insitu lysis of the cells and covalent immobilization of cell proteins on cyanogen bromide activated paper. The paper is then probed with rabbit anti-chymosin antibody followed by I-125 labeled protein A that binds to the rabbit antibody. A typical colony screening assay is shown on the next slide with positive and negative controls and identification of those cells producing chymosin.

Another important technique is Western Analysis where (slide) proteins are separated by SDS gel electrophoresis followed by transfer and covalent attachment to a paper support. From this point the assay is very similar to the colony screening assay discussed earlier. A typical autoradiograph (slide) provides information about the engineered protein such as its molecular weight and whether proteolytic breakdown of the chymosin has occurred. The analysis can be performed using whole cell.

The more successful cloning efforts, that is the insertion of foreign DNA into a new host organism, have been with yeast, Eshcherichia coli and Bacillus sp. . E.coli is a favorite of molecular biologists because so much is known about the genetic of the organism. The specific elements and techniques for the manipulation of the genetic material are also best understood in E.coli . Saccharomyces cerevisiae is also a logical host for chymosin production because of advances in recombinant DNA techniques and compatibility of the yeast with food applications. Bacillus offers the potential for high level secretion of the protein from the cell with significantly reduced processing costs. The major disadvantage with Bacillus lies in the fact that less information about the organism exists compared to E.coli or yeast.

Collaborative's efforts have been directed at engineering the prochymosin gene into yeast using plasmids as their vectors. The basic requirements for a vector are a yeast origin of replication and a selection marker to allow both identification and selective growth of cells containing the plasmid. In general, an E.coli origin of replication and selection marker are also added to allow convenient preparation of DNA in E.coli . Desirable features of a vector for

purposes of use and production are stability, high copy number, and availability of unique restriction sites for addition of genes and controlling elements. Evidence from several laboratories indicates that copy number plays a role in stability since high copy number plasmids are more stable. Factors which appear to influence plasmid copy number and stability are the origin of replication, the selection marker, and the size of the plasmid. The slide shows a few of the many vectors that Collaborative scientists have evaluated. Delta and phi refer to different two micron-based plasmids. The phi vector contains the entire two micron plasmid while delta vector has had portions deleted. Selection pressure is maintained by using genes coding for uracil or leucine metabolizing proteins on the plasmid and working in yeast strains that are deficient in these genes. Cir + and - refer to host strains with or without resident two micron circles. As you see using minimal media lacking uracil or leucine, plasmid stability of greater than 95% can be maintained through 18 generations of growth making these vectors suitable for industrial application.

Several yeast genes are transcribed at high levels and result in protein production in excess of 1% of the yeast's soluble protein. For example, the yeast glycolytic enzymes phosphoglycerate kinase (PGK) and triosephosphate isomerase (TPI) as well as the carbohydrate utilizing enzyme galactokinase (GAL1) are present at high levels in wild type yeast strains growing under certain physiological conditions. The transcriptional promoter regions from these genes may be borrowed for production of other messenger RNAs (such as prochymosin) and when placed on high copy number, stable plasmids, allow production of chymosin at the levels indicated. (slide) It isn't known at the present time if the differences in expression levels are a reflection of the relative promoter strength or a result of interactions between some portion of the prochymosin gene and the promoter at the DNA or mRNA level. While use of the GAL1 promoter in this comparison resulted in less prochymosin than production with the PGK or TPI promoter, the GAL1 promoter is also tightly regulated. In the absence of galactose or the presence of glucose, prochymosin production is at least 20-fold lower. This property should make the GAL1 promoter extremely useful for production of proteins which are toxic to yeast cells. At Dow, these strains of yeast have also had optimized media developed for the production of high density cell cultures of up to 35 dry grams per liter.

In spite of the high level production of prochymosin in these yeast strains, it is striking that very little of the prochymosin is activatable by the standard pH 2 activation of calf prochymosin. This fact, coupled with the observation that much of the prochymosin produced in yeast is not soluble in buffer but requires strong denaturing conditions such as 8M urea or 6M guanidine-HCl to solubilize it, suggests an aberrant structure for the prochymosin produced in yeast. These results agree with other groups who have engineered the prochymosin gene into yeast and E.coli obtaining comparable levels of expression of prochymosin that is largely insoluble and catalytically inactivatable by pH 2 activation. This same phenomenon has been observed for some other proteins expressed in E.coli or yeast such as human insulin fusion protein. Apparently the proteins are adopting an incorrect conformation due to aggregation of the molecule or improper disulfide bond formation. In fact, in E.coli the chymosin protein is segregated into inclusion bodies as seen in the following slide.

Since calf prochymosin is normally secreted from stomach cells it is thought that levels of catalytically active chymosin could be improved by secretion from a cell, this inducing the proper configuration. Secretion pathways and the genetic elements controlling them, however are not wholly understood. Bacillus has been of interest to Dow scientists as a very desirable host for secretion of genetically engineered proteins. The prochymosin gene has in fact been cloned into Bacillus. Current work with Bacillus continues to improve the level of expression and secretion of prochymosin.

Scientists at Collaborative have followed the same line of thinking in an attempt to improve the amount of correctly folded protein by secreting it from yeast. It is apparent from examples of secreted proteins from E.coli, yeast and animal cells that a hydrophobic sequence of amino acids usually located at the amino terminus of the protein plays a key role in directing the secretion of the molecule. Collaborative has examined the effect of using the natural calf secretion signal present on preprochymosin as well as the secretion signals for two yeast secreted proteins- invertase (SUC2) and alpha mating factor (MF alpha). The prochymosin coding sequence was joined to the genes for invertase and alpha factor at convenient restriction sites to yield fusion proteins of prochymosin joined to the secretion leader plus a few coding nucleotides for the yeast protein. In both cases, glycosylation acceptor sites of the form ASN-X-SER/THR would be present on the secretion leader portion of the fusion protein. Use of either the invertase or the alpha mating factor secretion signal results in glycosylation and secretion of prochymosin from the yeast cells into the medium(slide). The invertase sequence results in secretion of 10% of the prochymosin made while the alpha factor sequence is slightly less efficient. The natural calf secretion signal for chymosin does not direct the secretion of detectable levels of chymosin from yeast.

Glycosylation of the invertase- and alpha factor-prochymosin fusion proteins is consistent with their passage through the secretion pathway, where accessible ASN-X-SER/THR sequences are normally glycosylated in yeast. All glycosylation is removed from the fusion proteins by acid activation to chymosin thus all of the carbohydrate must have been added to the invertase and alpha factor portions of the fusion proteins and not to chymosin itself. The important point from these experiments is that all of the secreted prochymosin is activatable to chymosin by the same pH 2 activation method effective for prochymosin derived from calf. Prochymosin secreted from the yeast, unlike prochymosin synthesized in the yeast cytoplasm, is indistinguishable in activity and structure from prochymosin isolated from calf.

A different approach to the insolubility problem with prochymosin has been taken by Celltech and others. Celltech has developed procedures for the solubilization, renaturation and activation of prochymosin produced in E.coli to produce active chymosin. The Celltech procedure involves reversibly denaturing (or unfolding) the insoluble form of prochymosin and subsequently allowing the chymosin precursor to renature (or refold), producing active prochymosin. The Celltech procedure starts with frozen E.coli cells grown under conditions that induce methionine-prochymosin production. Cells are disrupted by incubation with Tris/EDTA/lysozyme followed by sodium deoxycholate and DNAase treatment to reduce the viscosity due to the nucleic acids. The insoluble prochymosin is harvested by

centrifugation, washed in buffer and recentrifuged. The pellet is then solubilized at room temperature in buffer containing 8 M urea or 6 M guanidine HCl and dilluted into 10 to 50 fold volumes of buffer at pH 10.7. They perform the dilution slowly and allow the solution to stand for a period of time until the pH is adjusted to 8.0. Remaining cell debris is then removed by centrifugation. The resulting prochymosin can then be acid activated to chymosin and is indistinguishable from calf chymosin (slide). Celltech claims that from 10 to 30 % of the insoluble prochymosin can be converted to active soluble chymosin. A patent application covering this process for production of chymosin was filed in June of 1982 in the United Kingdom (# GB2100737A). The Celltech procedure has been evaluated in our hands with similar reported results.

In conclusion, as you can see, our involvement in the engineering of chymosin has been extensive and diversified. We have learned a great deal about the cloning of proteins into bacteria and yeast, and sbout fermentation and biochemical process development from this and other projects. Future efforts will be centered on improvements by secretion and protein processing.

Presented by David M. Barbano, Assistant Professor, Cornell University, Ithaca, NY, at the 6th Biennial Cheese Industry Conference held on August 28-30, 1984, at Utah State University, Logan, Utah.

## MASTITIS, SOMATIC CELLS AND THEIR RELATIONSHIP TO CHEESE YIELD

- I. Somatic Cells - What are they and What do they do?
- II. How does high somatic cell count influence cheese yield?
- III. How much somatic cell associated proteolysis can be observed in individual farm milk?
- IV. Economic significance of high somatic cell count milk.
- V. Conclusions.

Cheese yield and quality are two very economically important aspects of cheese manufacturing. A cheese manufacturer wants to obtain the best possible yield and quality of product. Some product yield losses or quality defects can be the result of poor raw milk quality. While other losses and defects relate to poor or incomplete execution of good cheese manufacturing practices.

### I. SOMATIC CELLS - WHAT ARE THEY AND WHAT DO THEY DO?

A somatic cell that is found in milk is one of the body cells from the cow. As you know, your body contains many different kinds of cells that have many different functions. In milk we find several different types of somatic cells. The three major types are: 1) lymphocytes, 2) neutrophils, and 3) epithelial cells. The first two types of cells are white blood cells, while the epithelial cells are structural cells from the mammary gland.

All milk contains some level of somatic cells. In normal milk, these somatic cells will be mostly the epithelial type. When there is a bacterial infection, tissue damage, or other inflammation of the mammary tissue, the number of somatic cells in the milk may increase dramatically. However, an even more important observation is that the relative proportions of the different types of somatic cells present in milk also changes dramatically. This change is illustrated in Table 1.

Table 1. Change in Types of Somatic Cells Present when Comparing Normal and Mastitic Milks

Milk Type		Somatic Cell Type		
		Lymphocytes	Neutrophils	Epithelials
Normal	% of total	6.1	9.1	84.8
(100,000)	cell number	6,061	9,091	84,848
Subclinical	% of total	4.8	47.6	47.6
Mastitis	cell number	23,809	238,095	238,095
(500,000)	increase	3.9x	26x	2.8x
Clinical	% of total	2.6	71.6	25.8
Mastitis	cell number	25,848	716,000	258,182
(1,000,000)	increase	4.3x	79x	3.0x

In normal milk, greater than 80% of the somatic cells present are epithelial cells. As we compare the normal milk with 100,000 somatic cells per ml to milk from cows with subclinical mastitis (500,000 cells per ml), we see that the lymphocytes increase about 3.9 fold, the neutrophils increase 26 fold and the epithelial cells increase about 2.8 fold. Neutrophils make up nearly 50% of somatic cells present in subclinically mastitic milk. As we continue this comparison to include milk where clinical mastitis is present (>1,000,000 cells per ml), we see that the neutrophils continue to make up an increasing proportion of the somatic cells present.

Why does this shift in the proportion of somatic cell types occur as we go from normal milk to mastitic milk? The specific function of neutrophils, which are a type of white blood cell, is to destroy invading bacterial cells, foreign proteins, and tissue debris in area of tissue inflammation and infection. Therefore, in mastitis, which is an infection and inflammation of the mammary tissue, it is reasonable to expect an increase in the proportion of neutrophils to epithelial cells.

How do neutrophils fight infection? A neutrophil is a white blood cell that moves quickly to areas of tissue damage and infection. The neutrophils have a very potent arsenal of weapons at their disposal to fight infection. These weapons include extremely active proteases, lipases, phospholipases, and specific chemicals that are inhibitory to bacteria. All of these enzymes and bacterial inhibitors are carried into milk.

What else happens during a mastitic infection? Because of the mammary tissue damage resulting from the infection, there is a leakage of constituents of the blood plasma into the milk. Blood plasma contains many enzymes. At this point in time the most significant enzyme in relation to cheese yield is an enzyme called plasmin. Plasmin is a proteolytic enzyme that will breakdown milk casein. Most research information would indicate that this enzyme is not inactivated by normal milk pasteurization conditions.

## II. HOW DOES HIGH SOMATIC CELL COUNT INFLUENCE CHEESE YIELD?

Yield of cheese is dependent on two main factors: 1) cheese yield potential of the milk, and 2) manufacturing cheese yield efficiency. The cheese yield potential of any given milk is determined by its casein and milkfat content. This will set the upper limit on your cheese yield potential as calculated by the Van Slyke formula shown below.

$$\text{PERCENT YIELD} = \frac{(0.93F + (C - 0.1)) \cdot 1.09}{1 - W}$$

F = PERCENT FAT IN THE MILK

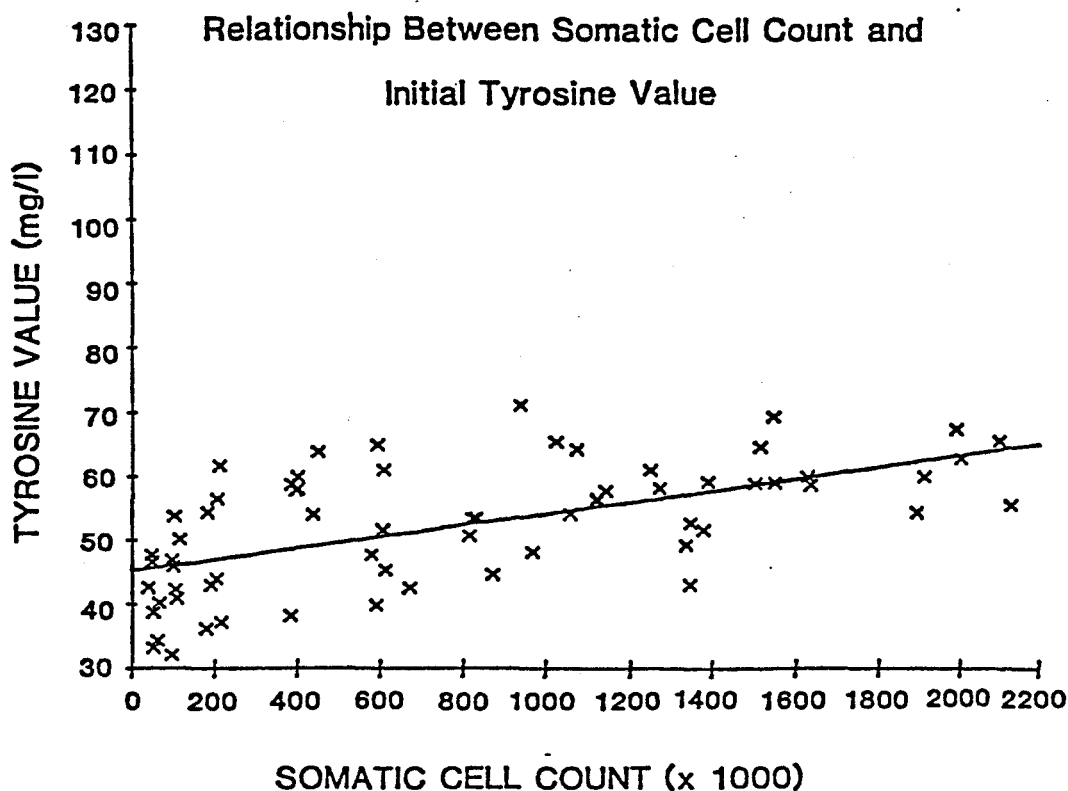
C = PERCENT CASEIN IN THE MILK

W = PERCENT MOISTURE IN THE CHEESE/100



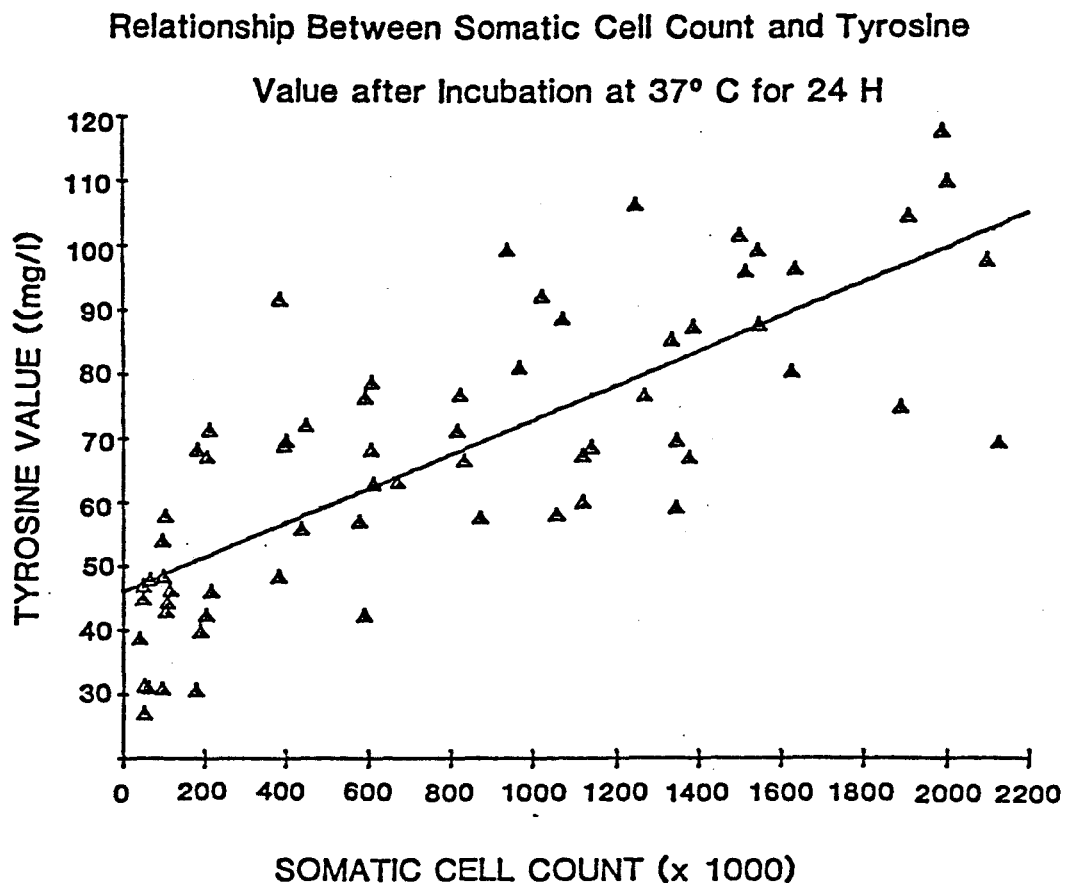
Yield of cheese is dependent on two main factors: 1) cheese potential of your milk and the manufacturing efficiency of your cheese plant. The proteolytic enzymes associated with neutrophils that are found in milk will actively attack and break down casein. There is evidence that an increase in the somatic cell count of milk is accompanied by an increase in proteolytic activity. It has always been said that high somatic cell milk had low casein but now it has become more apparent that the casein is actually being broken down. The tyrosine value is a chemical analysis method commonly used to measure the proteolytic damage in milk. The relationship between somatic cell count and the amount of proteolytic damage as measured by the tyrosine value is shown in figure 1 below. It is obvious that as the somatic cell count increases, the amount of small proteolysis products increases in fresh milk samples.

FIGURE 1



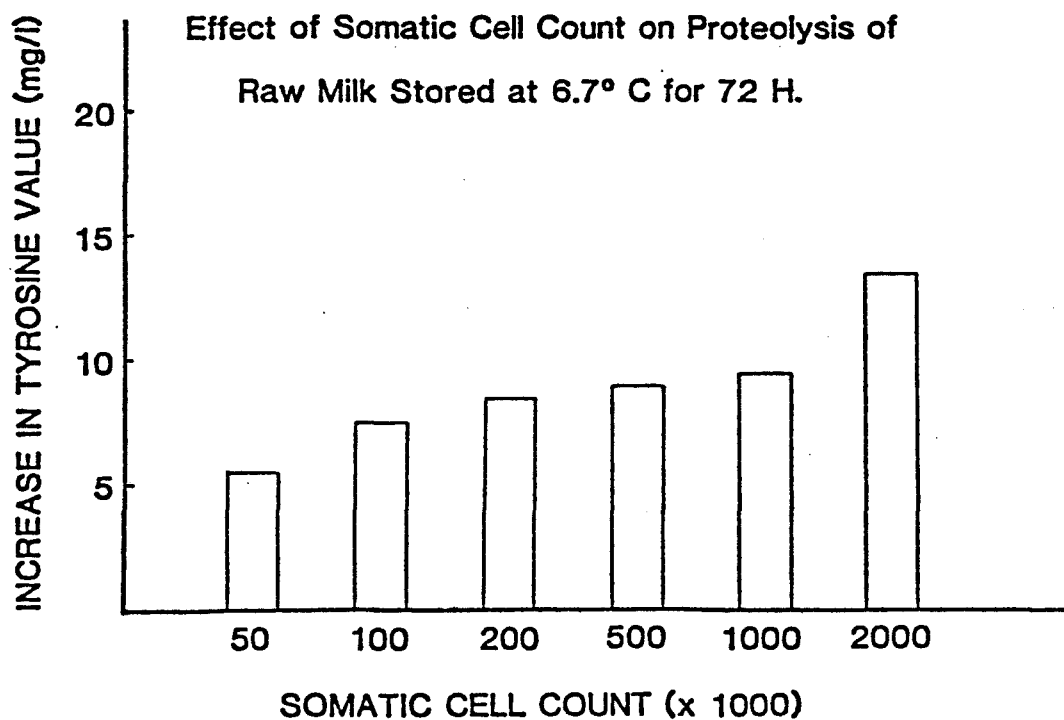
In order to determine the relationship between somatic cell count and the proteolytic activity in the same milks, dichromate preserved samples were incubated at 37°C for 24 hours to accelerate the proteolytic enzymatic reaction. The results are shown in figure 2 below. It is obvious from the comparison of figure 1 and figure 2 that as the milk somatic cell count increases, there is more proteolytic enzyme activity in the milk sample.

FIGURE 2



To observe the effect of refrigerated storage on the amount of proteolytic damage, milk samples were stored at 6.7°C for 72 hours and the results are shown in figure 3 below. As the somatic cell count increases, the amount of proteolysis increases.

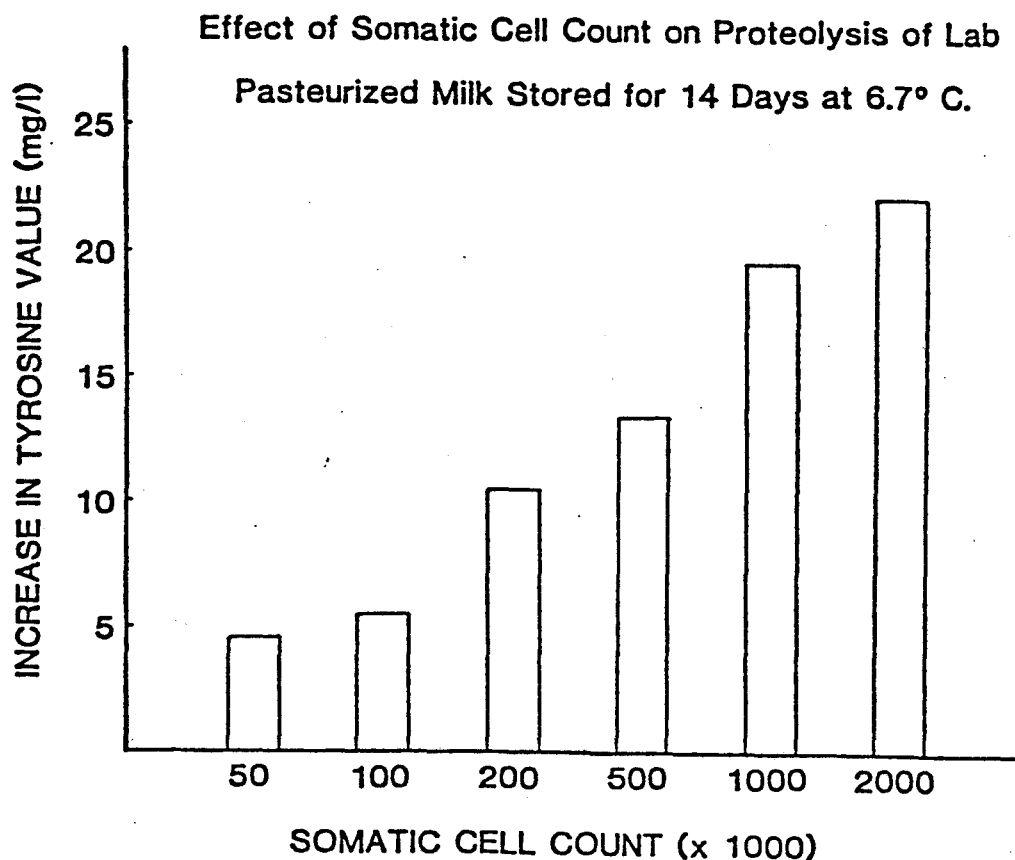
FIGURE 3



The fact that high somatic cell count milk has high proteolytic enzyme activity is very significant because this means that milk from one farm with a high somatic cell count will damage the cheese yield potential of other low somatic cell count milk. The damage will continue to increase during raw milk storage. Both proteolytic and lipolytic deterioration of milk may lead to off-flavor development in the finished product.

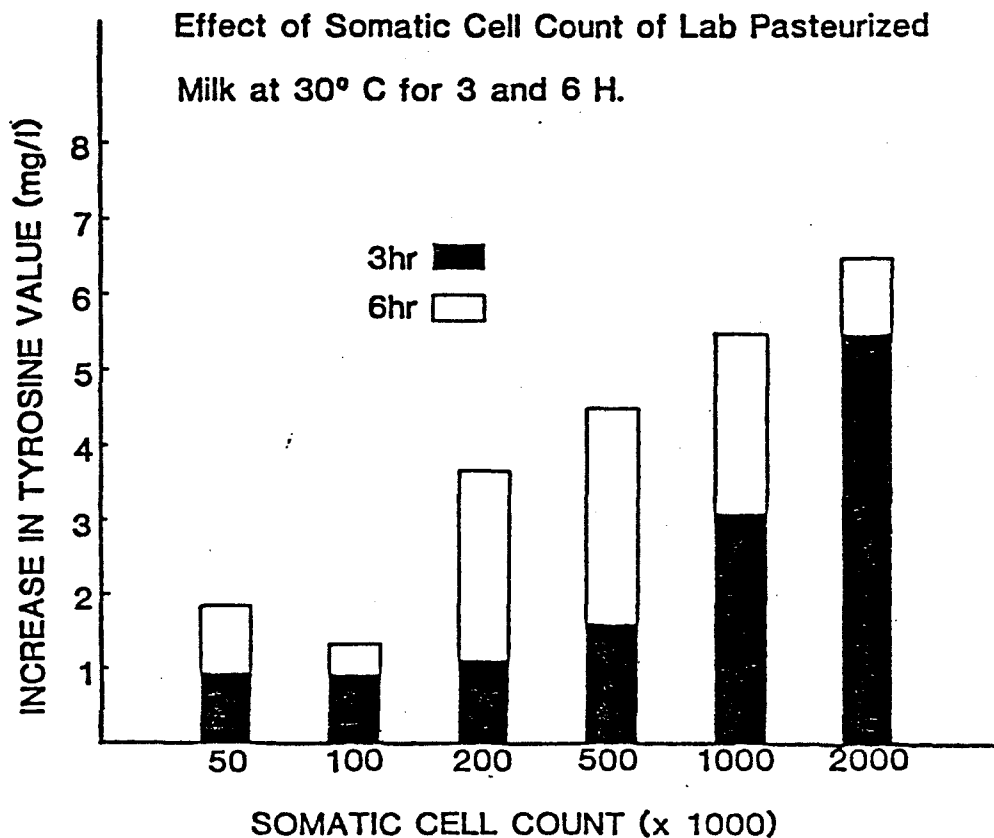
Some of the somatic cell associated proteolytic enzymes are not inactivated by pasteurization, and continue to breakdown milk protein while pasteurized milk is stored at 6.7°C for 14 days as shown in figure 4 below. Again, high somatic cell count milk has more proteolytic activity.

FIGURE 4



Also, as demonstrated by the results in figure 5 below, the proteolytic breakdown is accelerated by holding the milk for 3 and 6 hours at elevated temperatures. This temperature (30°C or 86°F) is similar to what would be used in the vats during cheese making. The data indicate that there is significantly more proteolytic breakdown after 6 hours in milk with 500,000 cells/ml versus milk with 100,000 cells/ml.

FIGURE 5



### III. HOW MUCH SOMATIC CELL ASSOCIATED PROTEOLYSIS CAN BE OBSERVED IN INDIVIDUAL FARM MILK?

A study was conducted on milk from 24 farms to evaluate the impact of somatic cells on the cheese yield value of milk. The actual amounts of true protein, nonprotein nitrogen, casein, and fat were determined on a fresh milk sample each month for each of the 24 farms for a one year period.

As shown in table 2 below, the selection of farms was based on their Wisconsin Mastitis Test history for the year 1982, the year prior to which our study was conducted. The assignment of farms to their respective groups remained constant throughout the study. An interesting observation that was made was that the high somatic cell group had more yearly variability in total protein than the low somatic cell group. Looking back at the data we collected for 1983 after the study was completed, we observed the same trends. The low somatic cell group had a lower yearly average Wisconsin Mastitis Test and had less variability in total protein.

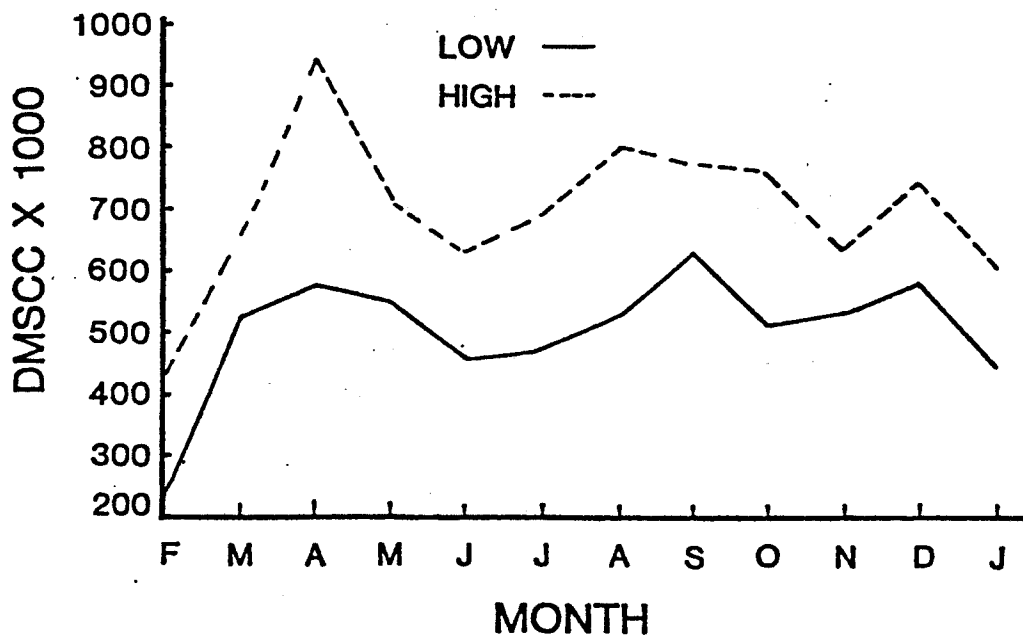
TABLE 2

#### RELATIONSHIP OF WISCONSIN MASTITIS TEST TO YEARLY VARIATION IN PERCENT MILK PROTEIN OF INDIVIDUAL FARMS

	NUMBER OF FARMS	YEARLY AVE. WMT	YEARLY RANGE IN PROTEIN
<hr/>			
<u>1982</u>			
LOW WMT	12	9.6 $\pm$ 1.48	0.43 $\pm$ 0.10
HIGH WMT	12	18.2 $\pm$ 1.20	0.61 $\pm$ 0.07
 <u>1983</u>			
LOW WMT	12	10.8 $\pm$ 3.33	0.44 $\pm$ 0.13
HIGH WMT	12	15.7 $\pm$ 4.27	0.55 $\pm$ 0.23
<hr/>			

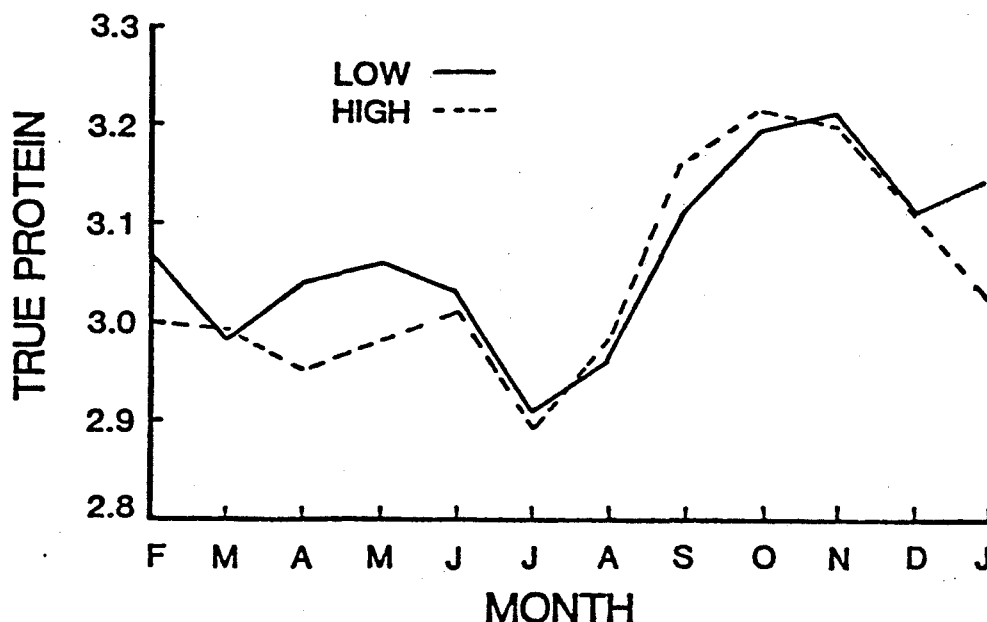
Direct microscopic somatic cell counts were also determined for each of the 24 farms and the results are shown in figure 6 below. In the next series of graphs the solid line represents the monthly average of all twelve low somatic cell farms and the dotted line represents the monthly average of all twelve high somatic cell farms. As can be seen in figure 6 below, the average direct microscopic somatic cell count for all 12 low somatic cell farms stayed consistently lower than the average direct microscopic somatic cell count for all 12 high somatic farms by about 150,000 cells/ml.

FIGURE 6



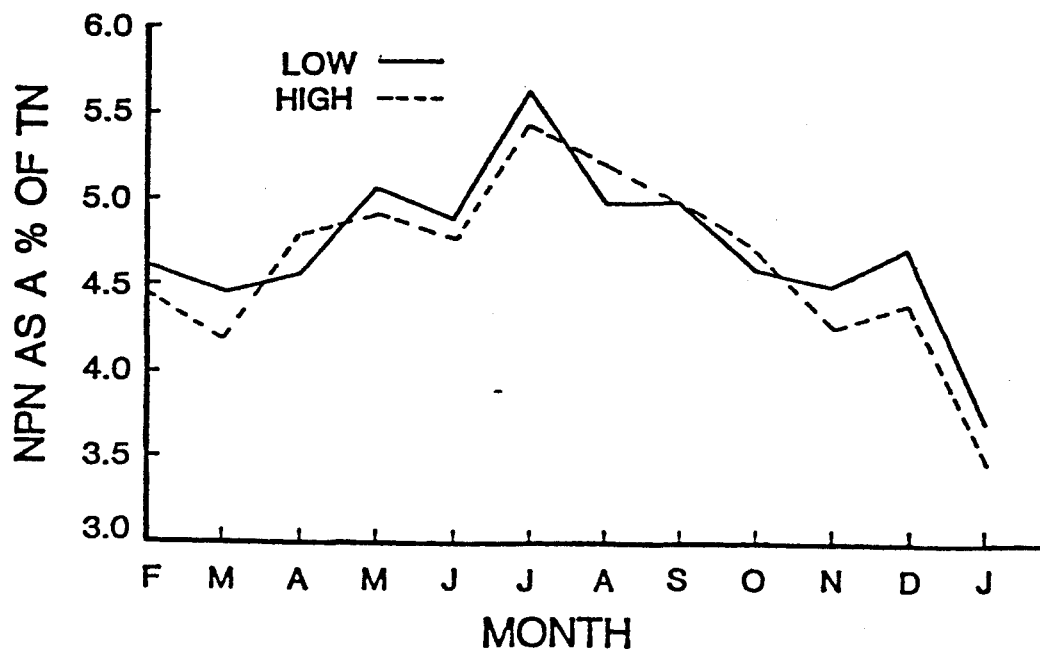
As can be observed in figure 7 below, no significant differences in true protein (total nitrogen - nonprotein nitrogen) were found between groups for any of the months studied. There is seasonal variability in the true protein content of farm milk, with the true protein content being highest in the winter months and lowest in the summer months.

FIGURE 7



By observing the data for nonprotein nitrogen shown in figure 8 below, we again see that there were no significant differences between high and low groups for any of the months studied. Also, there is seasonal variability in the nonprotein nitrogen content of milk. The nonprotein nitrogen content of milk is highest in the summer and lowest in the winter.

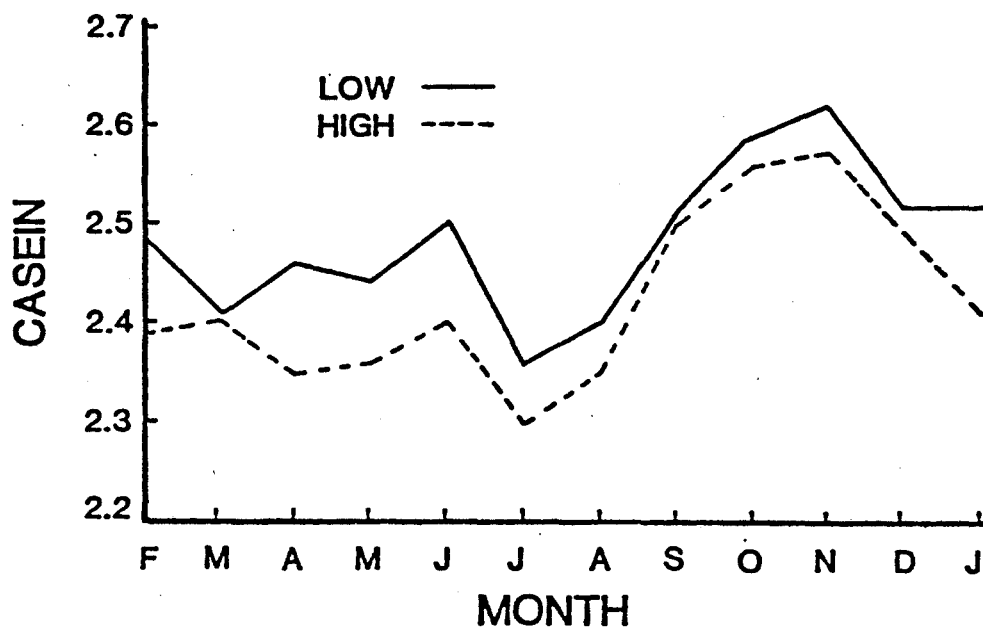
FIGURE 8





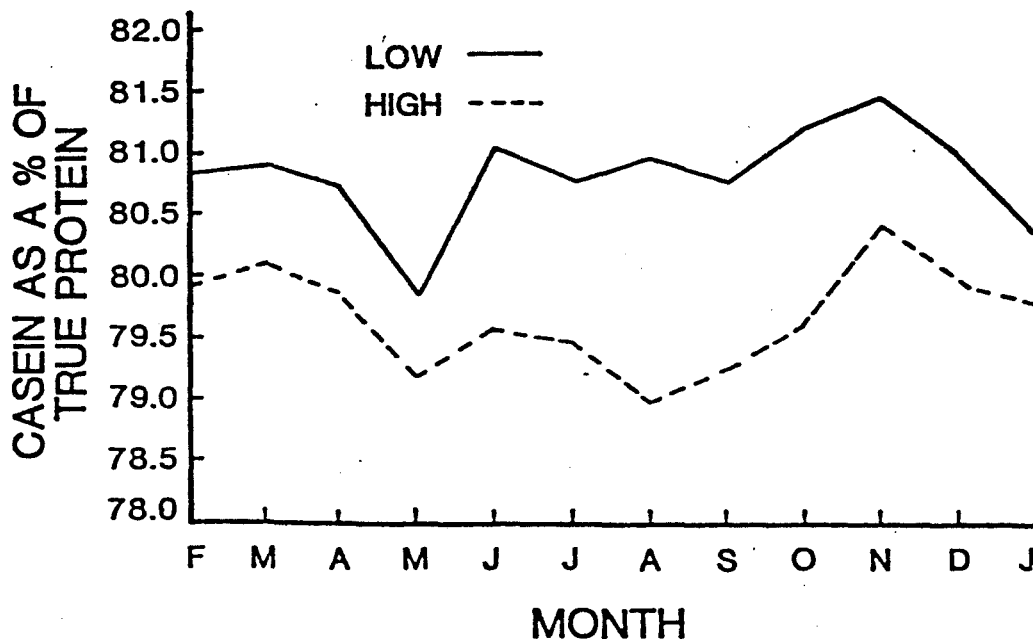
The data for percent casein is shown in figure 9 below. Again there were no significant differences between high and low groups for any of the months studied. There is seasonal variability in the casein content of milk with the casein content being highest in the winter months and lowest in the summer months.

FIGURE 9



However, when casein is expressed a percent of true protein, as seen in figure 10 below, there were significant differences between high and low somatic cell groups for 9 of the 12 months studied. When casein is expressed in this manner, there is no seasonal variability.

FIGURE 10



The observations that were drawn from this part of our study were that percent true protein, casein, and nonprotein nitrogen all varied seasonally but were unaffected by somatic cell count. Also, casein as a percent of true protein did not vary seasonally, but was lower in high somatic cell count milk.

In order to further investigate the proteolytic damage of casein, a more detailed investigation was undertaken. Once again the selection of farms for part 2 of this study was based upon their yearly average Wisconsin Mastitis Test history. The resulting somatic cell counts and yearly averages of the Wisconsin Mastitis Tests for the samples are shown in table 3 below.

TABLE 3

PART 2 - ASSESSMENT OF SOMATIC CELL ASSOCIATED  
PROTEOLYSIS IN FARM MILK SAMPLES

AVE. YEARLY WMT	DMSCC
8.57	176,000
19.39	673,000

Electrophoresis is an extremely sensitive technique used to determine the amount of individual proteins in milk. This method was compared to the traditional method used for determining casein which utilizes precipitation of casein at pH 4.6 and nitrogen determinations by Kjeldahl analysis. The relative percentages of the individual caseins as determined by electrophoresis are shown in table 4 below. All the casein proteolysis products were added and are expressed as one value. As one can see there is more casein proteolysis products and less intact casein in the high somatic cell milk.

TABLE 4

CASEIN	INITIAL MILK	
	LOW DMSCC	HIGH DMSCC
	----- % -----	
ALPHA <sub>s</sub>	45.8	36.9
BETA	32.4	24.2
KAPPA	10.3	8.9
PROTEOLYSIS PRODUCTS	11.5	30.0
TOTAL	100	100
CASEIN % OF TRUE PROTEIN	82.5	80.4

There is a discrepancy between the electrophoresis method and the traditional method of measuring casein in milk. Although the electrophoresis method indicates that 30% of the casein has been enzymatically damaged, the traditional method of casein analysis indicates that 80.4% of the true protein is present as casein. Therefore, the traditional method of measuring casein in milk is not as sensitive to the amount of casein proteolysis as the electrophoresis method.

#### IV. ECONOMIC SIGNIFICANCE OF HIGH SOMATIC CELL COUNT MILK.

The following is an economic analysis of the cheese yield potential of the milk that was analysed in the somatic cell study on the 24 farms. The cheese price was set at \$1.52/pound. The pay price for the milk was based on the class II milk price and fat differential for each individual month in Federal Milk Marketing Order No. 2. Assuming the milk was standardized to a casein to fat ratio of 0.7, the cream was valued at \$1.2 per pound of fat. The Van Slyke formula was used to calculate the theoretical cheese yield of the milk from each farm each month. Keep in mind that the values for casein and fat used in the formula were all determined exactly by analysis. The fat recovery in cheese making was assumed to be 90%. The moisture of the finished cheese was assumed to be 37%. A personal computer was used to analyze the data. The weight of milk used to determine the cheese yield was adjusted for the removal of the fat in the standardization of the casein to fat ratio.

The result for one typical farm of the 24 is shown in table 5 below. The program in the personal computer calculated the theoretical cheese yield and the value of the cheese plus the cream. The gross margin per hundredweight of milk was then determined by subtracting the price per hundredweight of milk from the value of the cheese plus cream. As you can see from table 5, the gross margin for handling this farm's milk varies from month to month due to changes in cheese yield potential. Overall, the gross margin for the year on handling milk from this farm was \$2.10.

TABLE 5  
SOMATIC CELL DATA

FARM 422

<u>MONTH</u>	<u>MILK FAT</u>	<u>MILK CASEIN</u>	<u>CHEESE YIELD</u>	<u>VALUE OF CHEESE + CREAM</u>	<u>CLASS II PRICE</u>	<u>GROSS MARGIN PER CWT</u>
1	3.44	2.38	9.23	14.10	12.55	1.55
2	3.45	2.42	9.39	14.27	12.53	1.74
3	3.52	2.50	9.63	14.64	12.52	2.12
4	3.57	2.56	9.82	14.92	12.54	2.38
5	3.68	2.63	10.11	15.36	12.69	2.67
6	3.43	2.58	9.63	14.64	12.17	2.37
7	3.48	2.42	9.39	14.31	12.49	1.82
8	3.49	2.36	9.13	14.10	12.56	1.54
9	3.63	2.64	10.05	15.27	12.77	2.13
10	3.59	2.52	9.78	14.86	12.73	2.13
11	3.59	2.52	9.78	14.86	12.77	2.09
12	3.52	2.46	9.55	14.53	12.20	2.33
AVERAGE	3.53	2.50	9.62	14.66	12.55	2.10

A yearly average was calculated for each farm in the high and low somatic cell groups and the two groups are compared in table 6 below. There is a trend of lower cheese yield and lower gross margin per hundredweight in the high somatic cell group.

TABLE 6

<u>FARM</u>	LOW SOMATIC CELL		HIGH SOMATIC CELL	
	<u>CHEESE YIELD</u>	<u>GROSS MARGIN/CWT</u>	<u>CHEESE YIELD</u>	<u>GROSS MARGIN/CWT</u>
1	9.62	2.104	8.90	1.44
2	9.70	2.135	8.92	1.42
3	9.27	1.79	9.62	2.10
4	9.30	1.82	9.04	1.57
5	9.59	2.13	8.65	1.20
6	10.41	2.81	10.01	2.53
7	9.98	2.39	9.12	1.64
8	9.54	2.05	9.71	2.19
9	9.36	1.84	9.54	2.13
10	8.93	1.45	9.65	2.10
11	9.35	1.86	8.93	1.49
12	9.21	1.71	8.99	1.50
AVERAGE	9.52	\$2.01	9.26	\$1.78

A comparison between the average direct microscopic somatic cell counts, cheese yield in pounds per hundredweight, and gross margin per hundred weight for the two groups is shown in table 7 below. An average difference of only 138,000 somatic cells/ml resulted in a cheese yield difference of 0.27 pounds per hundredweight. Once the value of extra cream in the high somatic cell group is subtracted from the extra value of cheese in the low somatic cell group the resulting cost difference is \$0.23 per hundredweight of milk.

TABLE 7

	<u>LOW</u>	<u>HIGH</u>	<u>DIFFERENCES</u>
SOMATIC CELLS	529,000	667,000	138,000
CHEESE YIELD (LB/CWT)	9.52 LBS	9.26 LBS	.27 LBS
GROSS MARGIN/CWT	\$2.01	\$1.78	\$.23

## V. CONCLUSIONS

### A) How do high somatic cell counts decrease cheese yields?

The result of high somatic cell counts is to decrease the casein content of milk which will result in a change in the casein to fat ratio. Decreased casein is the result of proteolytic damage to milk casein which results in a loss of the enzymatically damaged casein to the whey. A lower amount of casein for curd formation may also lead to higher fat losses in whey. There is information in the research literature which shows that high somatic cell count milk results in weaker curd strength, which may cause further losses of casein and fat to the whey.

## Helping Milk Producers Control Mastitis and Reduce Somatic Cell Counts 1.

Allen N. Bringe, Dairy Science Department  
University of Wisconsin - Madison, Wisconsin.

The facts presented at this conference indicate the need for the cheese and milk industry to communicate the definite advantage of marketing milk with lower somatic cell count. To reach the goal of higher milk quality which will result in higher cheese yield and quality means a concentrated effort in required by the industry.

The knowledge level of the employees communicating to the dairymen need to be at least equal to the top ten percent of the dairymen or better. These trained employees need to know current technology and have the attitude and ability to easily communicate facts in a manner that will result in adoption. To cause change in methods and practices, the ideas need to relate in ways that can be adopted on most dairy farms.

All of the dairymen understand what clinical mastitis is. I see your greatest challenge is to create an understanding of the significance of subclinical mastitis. Individual cow somatic cell count (SCC) is available as part of the DHI production testing program.

Currently 2.4 million cows are tested monthly in the National DHI program. Interest of producers is high concerning interpretation and use of these individual cow records. Recommendations based on these records usually relate to management decisions at the herd level. U of W research, 1984, shows that individual cow SCC when transformed to linear scores ( $LS = \log_2(SCC/100) + 3$ ) has a linear relationship to milk yield and mastitis treatment probability.

1. Presented at Sixth Biennial Cheese Industry Conference  
Utah State University, August 28-30, 1984.



Table 1. Conversion of cell count to linear score

Linear cell count score (LS)	Cell count (thousands)	
	Midpoint	Range
0	12.5	0 - 17
1	25	18 - 34
2	50	35 - 70
3	100	71 - 140
4	200	141 - 282
5	400	283 - 565
6	800	566 - 1130
7	1600	1131 - 2262
8	3200	2263 - 4525
9	6400	4526 -

Table 2. Lactation loss in milk yield associated with increase linear cell count score

Lactation average linear cell count score (LS)	Geometric lactation average somatic cell count	Yield loss	
		Lactation 1 (lbs./305 days)	Lactation 2
2	50	0	0
3	100	200	400
4	200	400	800
5	400	600	1200
6	800	800	1600
7	1600	1000	2000

The results of somatic cell count of the bulk tank if conducted accurately, can provide a good indication of the mastitis status. Herds with SCC over 500,000 have serious subclinical mastitis problems. The regulatory message that is enforced does not inform dairymen of the effect on milk quality, yield, or udder health. The bulk milk SCC does not identify problem cows or the factors contributing the high counts.

The California Mastitis Test (CMT) on milk from each quarter can be of value as a management tool if it is conducted and summarized on a routine basis. Since most dairymen find this difficult to do, the effective record program offered by DHI.

Goals  
Bulk tank  
     $< 200,000$  SCC  
     $< 10,000$  SPC

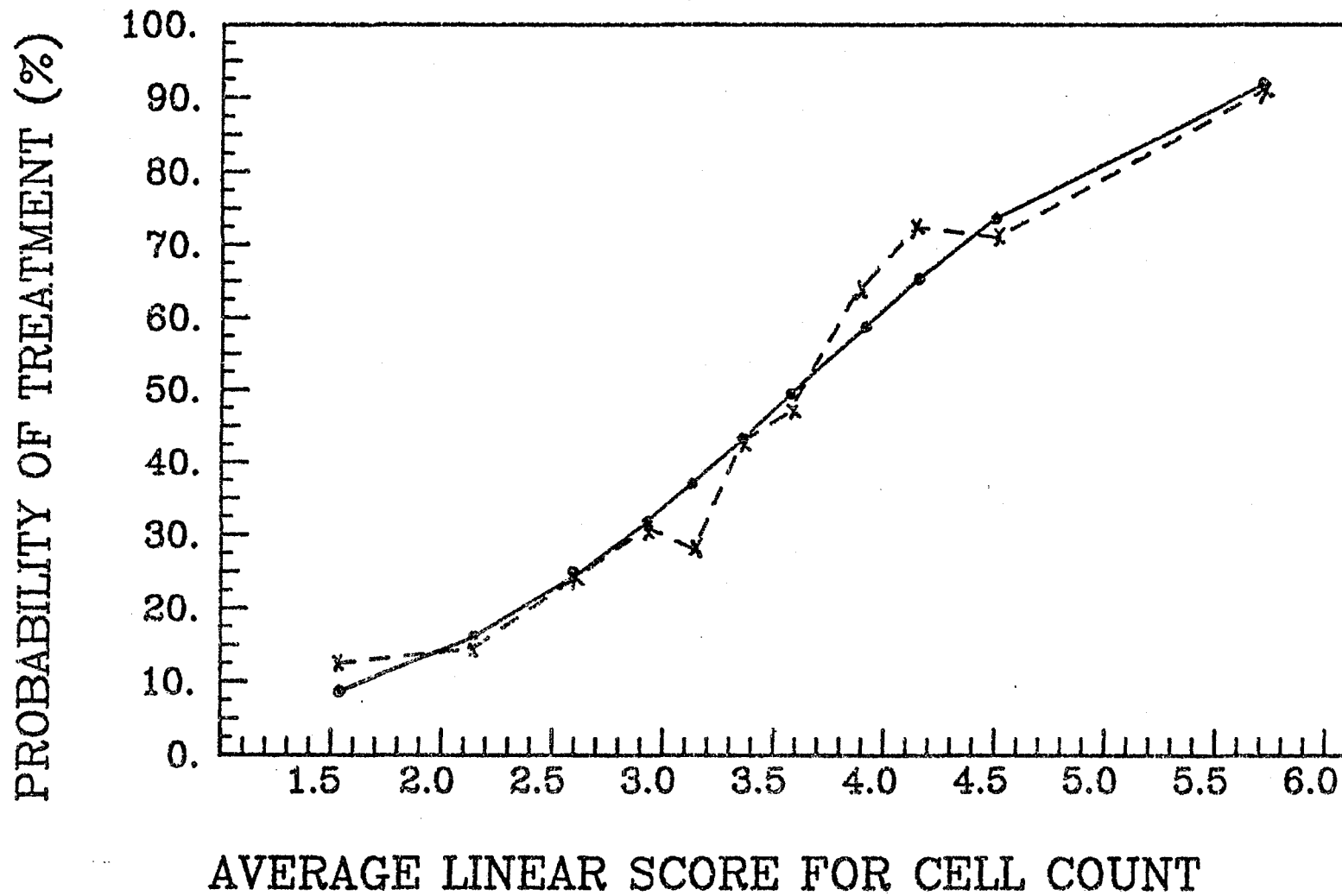
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DHI SCC  
     $< 2000$   
    Linear  $< 3$   
    90-92%  $< 40000$   
    85%  $< 200000$

---

Cows  
     $< 250$

Figure 1. Predicted (solid line) and actual (broken line) percent of cows treated for mastitis by lactation average linear score.



## IMPLEMENTATION OF A MASTITIS CONTROL PROGRAM

To properly implement a mastitis control program a dairyman must be willing to make the necessary changes to correct any deficiencies regarding:

1. Housing and environment - need clean, dry, well-bedded stalls and well-drained yards.
2. Properly operating and installed milking equipment.
3. Managed milking procedure including the use of an approved, effective teat dip at each milking. Dry cow treat with sterile single dose antibiotic.

## Interpretation of the Somatic Cell Report

1. Cows with cell counts over 600,000 cells, excluding samples taken the first or last two weeks of lactation, can be considered infected cows. Cows with two samples with readings of over 200,000 can also be considered infected.
2. Lactation treatment of infected cows, if effective, will cause cell counts to go down. There may be a delay of several weeks or so in the decline in cell counts depending upon the organisms involved. It is likely that the treatment will reduce the organisms and the cell count temporarily but not eliminate the infection. If the cell count remains high or goes down and comes back up, the treatment was ineffective.
3. First-calf heifers normally freshen without mastitis and with very low cell counts (10,000 to 50,000 cells). The normal cell count gradually increases as the cow becomes older and has been exposed to injury and infection.
4. Cows with cell counts below 200,000 have a low probability of infection. Some infected cows may occasionally dip below this level. Studies indicate milk production loss when over 50,000 SCC.
5. Cows with cell counts between 200,000 and 600,000 can be considered likely infected. Once this level occurs, some damage is being done and milk loss is occurring.
6. The DHI cell Count obviously does not indicate which quarter or quarters are infected. Infected quarters can be identified by the California Mastitis Test (CMT) paddle.
7. Cows infected with the less severe mastitis organisms will increase gradually in cell counts but may not show clinical (visible) mastitis. Seventy-five percent of the infected quarters do not show symptoms other than the high cell counts. The chronic cases will show occasional flare-ups. You can estimate that for every quarter that shows milk symptoms like flakes or actual flare-ups, there are at least 10 or 20 other infected quarters showing no visible symptoms.
8. It is possible for cows with low cell counts to suddenly flare up with severe mastitis without prior warning. These cases are usually due to the environmental organisms such as the coliforms.
9. We do not have complete information on factors other than infection, age and stage of lactation which influence cell counts. The infection is by far the most important. However, other stresses without infection, such as a stepped on teat or udder injury, may result in a high cell count.
10. Goals concerning SCC are printed in the lower right hand corner at the bottom of the SCC report. Compare your herd average to the goals. The application of mastitis prevention techniques will assist in reaching these practical goals for efficient herd production. The weighted average reflects the average cell count for your herd based on the pounds of milk and cell counts reported for each cow on the test date. The average linear score for the herd of 3.0 is a excellent goal to aim for with mastitis prevention programs. It will be difficult to continually have 85 percent of cows below 200,000. Watch the effect of environment at various months of the year. Correct problems so the herd is not exposed to continual reinfection.

### How to Use The Somatic Cell Report

It takes some experience to learn how to use the DHI somatic cell counts, but experiences of the dairymen using them suggest that they can be used in the following ways:

1. Extent of the mastitis problem in a herd can be easily monitored. Observe the percent of the herd greater than 200,000. Increases means a breakdown in milking management, milking machine or environment. A correction of herd management problems should result in lowering percent of herd over 200,000.
2. Cows can be selected for dry therapy by examining the cell count history for the current lactation.
3. Treatment during the lactation solely on the basis of the cell count is usually not recommended. Dry treatment is usually more effective and does not require discarding milk. However, it may be useful to treat cows infected in early lactation to prevent continued milk loss throughout the rest of the lactation.
4. In herds with a high level of mastitis, the practices which appear most useful are: make sure that the milking equipment and general sanitation are optimum, teat dipping after each milking and dry treatment of all quarters at drying off. After the incidence is reduced (weighted herd average below 400,000), it is suggested that selective dry therapy be used. Selective dry therapy is also recommended in those herds with below-average incidence.
5. Cooperation with the local veterinarian is desirable and veterinarians seem to welcome the availability of the cell counts so they also can monitor the mastitis problem in the herd. The veterinarian can culture all high count (non clinical) cows to determine organisms and drug sensitivity. He can recommend a lactation product to use for clinical cases and a product for dry treatment.
6. Dairymen using the program have found cell counts useful in the culling program. Cows with continuing cell counts over 600,000 cells despite treatment are candidates for culling because they are a continuing source of infection for the other cows.
7. Improvements in the market's control program can be observed within six months. Do not expect miracles. The first calf heifers are the best animals to evaluate if the prevention program is effective.

SIXTH BIENNIAL CHEESE INDUSTRY CONFERENCE

UTAH STATE UNIVERSITY

AUGUST 28-30, 1984

ON-FARM ULTRAFILTRATION OF MILK: A NATIONAL STUDY

A.J. LUKSAS

LAST YEAR THE DAIRY FARMERS IN THE UNITED STATES PRODUCED 140,000,000,000 LBS. OF MILK. ABOUT ONE-THIRD OF THAT MILK OR 50,000,000,000 LBS. IS PROCESSED INTO CHEESE, WHICH RESULTS INTO APPROXIMATELY 5,000,000,000 LBS. OF CHEESE AND 45,000,000,000 LBS. OF WHEY. HALF THE WHEY IS PROCESSED FURTHER INTO FOOD OR FEED PRODUCTS, THE REST OR APPROXIMATELY 20,000,000,000 LBS. PLUS IS DUMPED ON THE FIELDS, LAND FILL, STREAMS, MUNICIPAL DISPOSAL SYSTEM, THEREFORE CREATING A POLLUTION OR DISPOSAL PROBLEM.

THE WHEY THAT IS UTILIZED IN FOOD OR FEED PRODUCTS COMES FROM THE LARGER CHEESE PLANTS. THE WHEY THAT IS NOT UTILIZED IN FOOD OR FEED PRODUCTS RESULTS MAINLY FROM THE SMALLER PLANTS THAT CANNOT AFFORD TO INSTALL THE NECESSARY EQUIPMENT TO PROCESS THE WHEY DUE TO COSTS CONSTRAINTS OR SHIP IT TO LARGER CHEESE PRODUCING PLANTS FOR PROCESSING BECAUSE OF COST IN SHIPPING SINGLE STRENGTH WHEY. EVEN THE COST EFFECTIVE

CHEESE-WHEY PROCESSING PLANTS WOULD BE MORE COST EFFECTIVE IF THEY HAD A WHEY THAT WAS MORE CONCENTRATED IN TOTAL SOLIDS AND HAD LESS LACTOSE AND ASH.

THE PROPOSED ON-FARM ULTRAFILTRATION DEMONSTRATION PROJECT IN CALIFORNIA WILL PROVIDE THE CHEESE PROCESSOR THAT UTILIZES WHEY MORE CONCENTRATED WHEY WITH LACTOSE AND ASH REDUCED. THE CHEESE PROCESSORS THAT CANNOT ECONOMICALLY PROCESS WHEY INTO SALEABLE PRODUCTS TODAY, MAY BE ABLE WITH THE ON-FARM ULTRAFILTRATION TO NOW PROCESS THEIR WHEY INTO SALEABLE ITEMS ECONOMICALLY AND BY DOING SO ELIMINATE OR MINIMIZE POLLUTION. THE SUCCESSFUL AND WIDESPREAD APPLICATION OF ULTRAFILTRATION TECHNOLOGY WILL GO A LONG WAY IN ELIMINATING THE 20,000,000,000 PLUS WHEY DISPOSAL PROBLEM MENTIONED ABOVE BY LEAVING THE LACTOSE AND ASH STREAM ON THE FARM TO BE FEED BACK TO THE MILK PRODUCING COW.

THEREFORE, ON-FARM ULTRAFILTRATION MAKES SENSE IN CENTS TO THE FARMER AND CHEESE PRODUCER. DRINC HAVING FOLLOWED THE ULTRAFILTRATION TECHNOLOGY DEVELOPMENTS AND REALIZING THEIR IMPORTANCE AND APPLICABILITY TO THE DAIRY FARMER AS A MEANS OF INCREASING QUALITY, ADDING VALUE TO MILK, AND DECREASING COSTS OF TRANSPORTATION, DECIDED TO EXPLORE THIS AREA FURTHER. AT THAT TIME, SOME WORK HAD BEEN DONE AT VARIOUS UNIVERSITIES, IN EXPLORATION AND APPLICATION OF THESE DEVELOPMENTS.

DRINC IDENTIFIED DR. ROBERT ZALL AT CORNELL, AS ONE OF THE LEADERS IN THE APPLICATION OF ULTRAFILTRATION TECHNOLOGY TO DAIRY PROCESSING. HE HAD ALREADY EXPLORED THE FRACTIONATION AND CONCENTRATION OF MILK BY THE ULTRAFILTRATION PROCESS AND FOUND THAT A HEATING STEP WAS BENEFICIAL FOR QUALITY AND APPLICABILITY OF THE FINAL PRODUCT BEFORE ULTRAFILTRATION. HE WAS INTERESTED IN EXPLORING THIS TECHNOLOGY FURTHER, DRINC WAS INTERESTED IN SUPPORTING HIS EFFORTS.

THEREFORE, ABOUT TWO YEARS AGO, THE BOARD OF DIRECTORS OF DRINC AND UDIA APPROVED THE FUNDS FOR THE ON-FARM FRACTIONATION PROJECT AT CORNELL UNDER THE DIRECTION OF DR. ZALL. OF COURSE, IT WAS UNDERSTOOD AT THAT TIME, THAT IF THE PROJECT WAS SUCCESSFUL THE NEXT STEP WAS TO SCALE THE PROCESS TO A FARM FOR DEMONSTRATION.

DR. ZALL'S WORK AT CORNELL WAS TO DEMONSTRATE THE RELIABILITY AND UTILITY OF MEMBRANE HARDWARE ON A DAY-TO-DAY BASIS AT A DAIRY FARM, DAIRY RESEARCH, INC. (DRINC) IN CONCERT WITH CORNELL UNIVERSITY RESEARCHERS FROM THE DEPARTMENT OF FOOD SCIENCE INSTALLED A UF MEMBRANE PLANT AT CORNELL'S TEACHING AND RESEARCH FARM AT HARTFORD, NEW YORK, WHERE APPROXIMATELY 400 COWS ARE MILKED TWICE DAILY. DR. ZALL, SELECTED AN ABCORE UF-90S MEMBRANE SYSTEM CONTAINING TWO SPIRAL WOUND MODULES CAPABLE OF RUNNING ONE THOUSAND POUNDS PER



HOUR. A UNIT OF THIS SIZE IS CAPABLE OF HANDLING MILK PRODUCED FROM 200 COW DAIRY. EQUIPMENT CHOICE THEN WAS MADE ON THE BASIS THAT THE SYSTEM SELECTED HAD GOOD OPERATING RECORD AT DIFFERENT PLANTS AROUND THE WORLD. AND THE PROJECT DIRECTOR HAD FIRSTHAND EXPERIENCE WITH THE EQUIPMENT.

MILK WAS THERMALIZED AT 70°C FOR 10 SECONDS, COOLED TO 40°C, AND PUMPED THROUGH THE MEMBRANE PROCESSING UNIT TO FRACTIONATE ACCORDING TO THE EXPERIMENTAL DESIGN. POST-MEMBRANE TREATMENT MILK WAS COOLED AND STORED IN A REFRIGERATED BULK TANK FOR 24 TO 48 HOURS. MILK WAS PUT INTO STAINLESS STEEL CANS AND TRANSPORTED EITHER TO THE CORNELL DAIRY PLANT OR TO A FOOD SCIENCE LABORATORY WHERE THE CONCENTRATES WERE CONVERTED INTO DIFFERENT MILK PRODUCTS SUCH AS YOGURT, COTTAGE CHEESE, CHEDDAR CHEESE, ICE CREAM, CULTURED BUTTERMILK, AND FLUID MILK.

WITHIN THE CONSTRAINTS OF TIME, STAFF AND FUNDS ASSIGNED TO THE PROJECT, WORK WAS CARRIED OUT TO LEARN WHAT MIGHT BE THE PREFERRED LIMIT OF CONCENTRATION TO USE IN MAKING COTTAGE AND CHEDDAR CHEESE WITH EXISTING CHEESE-MAKING TECHNOLOGY. THE STUDY SHOWED THAT BY FRACTIONATING MILK UP TO TWOFOLD LEVEL (OR HALF OF THE VOLUME) THAT BOTH TYPES OF CHEESE CAN BE MADE WITH GOOD RESULTS. WHEN MILK WAS CONCENTRATED MORE THAN TWOFOLD, IT TENDS TO BECOME UNSUITABLE FOR USE IN MAKING COTTAGE AND CHEDDAR CHEESE USING CONVENTIONAL METHODS.

<u>HALF VOLUME REDUCTION CONCENTRATE</u>			<u>THREE-QUARTER REDUCTION CONCENTRATE</u>	
. FAT	7.12	(/.12)	14.24	(14.24)
. PROTEIN	6.15	(6.10)	12.10	(11.88)
. LACTOSE	5.30	(5.58)	5.64	(6.36)
. ASH	0.73	(0.84)	1.02	(1.14)
. TOTAL SOLIDS	19.30	(19.64)	33.50	(33.80)

THIS DATA IS THE RESULT FROM ACTUAL WORK AND SOME EXTRAPOLATION.

( ) THEORETICAL VALUE FIGURES OF PERFORMANCE OF MEMBRANES.

AS TO MONITORING THE MEMBRANE PLANT FOR SELECTED QUALITY CONTROL PARAMETERS, THE FOLLOWING METHODS WERE USED. MEMBRANE PLANT OPERATED WITH MILK FOUR DAYS PER WEEK AND CLEANED ACCORDING TO METHOD RECOMMENDED BY THE EQUIPMENT SUPPLIER. MILK QUALITY BOTH BEFORE AND AFTER PROCESSING WAS GRADED USING STANDARD PLATE COUNTS, PSYCHOTROPHIC PLATE COUNTS, ACID DEGREE VALUE AND FOR INHIBITORY SUBSTANCES USING THE DELVOTEST METHODS. CLEANING WATER USED TO WASH EQUIPMENT WAS SOFTEN TO ZERO HARDNESS USING A 400 GALLON PER MINUTE AGWAY SODIUM ZIOLITE SYSTEM.

FINISHED GOODS MADE FROM EXPERIMENTAL CONCENTRATES WERE GRADED FOR EDIBLE QUALITY PARAMETERS USING STAFF WORKING WITH THE PROJECT DIRECTOR. TASTE PANELS WOULD BE MADE UP OF THREE OR MORE FOOD SCIENCE SPECIALISTS

WHO WERE FAMILIAR WITH PHYSICAL CHARACTERISTICS OF THE MILK BASED PRODUCTS BEING MANUFACTURED. FINISHED GOODS WERE MADE FOR SALE PRODUCTS AND THEN DISTRIBUTED THROUGH THE REGULAR OUTLET OF THE DAIRY PLANT AND ITS DAIRY STORE.

DURING DR. ZALL'S ON-FARM ULTRAFILTRATION RESEARCH AT CORNELL, THE CALIFORNIA MILK ADVISORY BOARD (CMAB) EXPRESSED AN INTEREST IN THE PROJECT. IN ANTICIPATION OF THE FAVORABLE RESULTS, CMAB SELECTED IN CALIFORNIA A FARM THAT WOULD BE LARGE ENOUGH TO PROVIDE QUANTITIES OF FRACTIONATED MILK THAT WOULD BE SUFFICIENT TO PRODUCE VATS OF CHEESE IN CHEESE-PRODUCING PLANTS. CMAB, REALIZING THAT THE PROJECT SHOULD BE A NATIONAL PROJECT, APPROACHED DRINC FOR SHARED SUPPORT AND PROJECT MANAGEMENT. DRINC AND CMAB REALIZING THAT THIS IS A NEW AREA OF EXPLORATION AND APPLICATION TO THE DAIRY FARM, REQUESTED PERMISSION FROM CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE, BUREAU OF MILK AND DAIRY FOODS CONTROL TO PRODUCE THE ULTRAFILTRATE ON THE FARM, TRANSPORT THE ULTRAFILTRATE TO THE CHEESE PLANT, PROCESS THE ULTRAFILTRATE INTO CHEESE, AND SELL THE RESULTING CHEESE WITHIN THE STATE OF CALIFORNIA AND, THEREFORE, BE ABLE TO CARRY EVERY SEGMENT OF THE PROJECT OUT TO ULTIMATE CONCLUSION.

SINCE THE DAIRY FARMER (PRODUCER) CHOSEN IS LARGE ENOUGH TO PROVIDE QUANTITIES OF ULTRAFILTERED MILK THAT CAN BE TRANSPORTED AND SEGREGATED ALL THE WAY TO THE CHEESE PLANT, COMMINGLING WITH UNPROCESSED (NOT ULTRAFILTERED MILK) WILL BE MINIMIZED. THE CHEESE PROCESSOR WILL ALSO HAVE SUFFICIENT QUANTITIES OF ULTRAFILTERED MILK SO THAT HE TOO CAN ISOLATE THE ULTRAFILTERED MILK/CHEESE BATCH FROM THE REST OF THE PRODUCTION.

THE INTENT IS TO PRODUCE THE VARIOUS TYPES OF CHEESES AND MARKET THEM WITHIN THE STATE OF CALIFORNIA TO DETERMINE IF THE CONSUMER WILL ACCEPT THE CHEESE WITHIN THE NORMAL CHANNELS OF DISTRIBUTION. THEREFORE, WE DID NOT WANT TO LABEL AS SOME REGULATORS SUGGESTED, THE CHEESE "MADE FROM ULTRAFILTERED MILK," SINCE THAT'S STATEMENT WOULD CALL TO CONSUMER'S ATTENTION THE FACT THAT THE CHEESE IS DIFFERENT. THAT DIFFERENCE CAN, IN FACT, GIVE US THE WRONG RESULTS WITH RESPECT TO THE CONSUMER'S ACCEPTANCE OF THE CHEESE. WE FURTHER FELT THAT THERE IS NO NEED TO ISOLATE THE ULTRAFILTERED MILK AS A PROCESS THAT IS SOMEHOW UN-NATURAL IN THE COURSE OF CHEESE MANUFACTURE. IN ULTRAFILTRATION WE DO NOTHING DIFFERENT THAN IS ACCOMPLISHED IN CHEESE MANUFACTURE EXCEPT THAT WE START THE PROCESSING AT THE FARM AND FINISH THE PROCESS IN THE CHEESE VAT. WE FURTHER FELT THAT THE PROCESS IS COVERED BY THE

ALTERNATE METHOD FOR CHEESE MANUFACTURE IN THE  
STANDARDS OF INDEMNITY FOR CHEESE.

AS WE ALSO KNOW, FDA HAS EXPRESSED CONCERN WITH THIS APPROACH TO CHEESE MANUFACTURE. THIS CONCERN IS TO DO WITH THE FINAL CHEESE MADE BY THE ALTERNATE METHOD OF CHEESE MANUFACTURE TO BEING AT LEAST NUTRITIONALLY EQUIVALENT TO THE PRESENTLY PROCESSED CHEESE. IN OUR OPINION THEY TOO WOULD WELCOME DATA THAT WOULD CLARIFY THEIR CONCERNS. THE PROPOSED PROJECT CAN PROVIDE THAT DATA AND MORE. AND ULTIMATELY, IT IS THE ONLY COURSE OF ACTION THAT CAN GENERATE THE DATA NEEDED TO ELIMINATE EVERYONE'S CONCERN AT EVERY CONCEIVABLE LEVEL OF MILK PROCESSING UP TO AND INCLUDING CHEESE PRODUCTION.

CALIFORNIA EXPRESSED A DEEP INTEREST IN THE PROJECT AND ASSURED US TO EXPEDITE THE REGULATORY CONSTRAINTS BEFORE IMPLEMENTATION SO AS TO ALLOW THE PROJECT TO PROCEED. BUT, BEFORE THEY PROCEEDED, THEY DID INDICATE THAT THEY NEEDED TO KNOW FDA'S FEELINGS AND CONCERNS OF RUNNING THE PROJECT IN CALIFORNIA.

WE, THEREFORE, APPROACHED FDA AND EXPLAINED THE PROJECT TO THEM IN DETAIL. THEY HAD MANY QUESTIONS, SHOWED HIGH DEGREE OF INTEREST, AND AGREED TO PROVIDE INPUT AS TO THEIR NEEDS. THEY FURTHER STATED THAT THEY WOULD NOT INTERFERE IN CALIFORNIA PROVIDING THE RESULTING

CHEESE DOES NOT CROSS STATE LINES. THEY ALSO INDICATED THAT THEY WILL EAGERLY AWAIT THE RESULTS TO DETERMINE IF IN FACT THE CHEESE RESULTING FROM UF MEMBRANE IS WELL WITHIN THE STATISTICAL RANGE ANTICIPATED FOR THAT CHEESE. THEY FURTHER INDICATED, BASED ON THE DATA GENERATED, THAT THEY WOULD DECIDE WHETHER THE CHEESE STANDARDS NEED TO BE AMENDED AND TO WHAT EXTENT TO PROVIDE FOR INTERSTATE SHIPMENT OF UF CHEESE.

IN ORDER TO POSITION THE ON-FARM ULTRAFILTRATION IN ITS PROPER PERSPECTIVE, I WILL REVIEW BRIEFLY WITH YOU THE UF PROCESS THAT WE WILL BE USING. ULTRAFILTRATION IS A SEPARATION PROCESS THAT CAN BE USED FOR SELECTIVELY SEPARATING BIOLOGICAL COMPONENTS IN LIQUID MIXTURE. ULTRAFILTRATION AS A COMMERCIAL PROCESS HAS BEEN IN EXISTENCE SINCE 1968, BUT HAS NOT BEEN UTILIZED EXTENSIVELY IN FOOD MANUFACTURING UNTIL THE ADVENT OF PRESENT DAY MEMBRANE DEVELOPMENTS. PRESENT DAY MEMBRANE INTRODUCED ABOUT TEN YEARS AGO, ARE PRODUCED FROM POLYSULPHONE POLYMER, WHICH MAKES THEM HIGHLY DURABLE AND CLEANABLE BY DAIRY CLEANING CHEMICALS. THE ULTRAFILTRATION SYSTEMS HAVE BEEN IN OPERATION AT FOOD AND DAIRY PLANTS FOR LEAST EIGHT TO TEN YEARS. THESE OPERATIONS HAVE DEMONSTRATED THAT ULTRAFILTRATION MEMBRANES ARE DURABLE UNDER PLANT OPERATING CONDITIONS AND CLEANING REGIMES WITH ACCEPTABLE LONGEVITY. ULTRAFILTRATION MEMBRANES NORMALLY CARRY A ONE YEAR

WARRANTY, AND ARE RELATIVELY INEXPENSIVE TO REPLACE. IT IS NOT UNUSUAL TO SEE UF MEMBRANES OPERATING TWO YEARS WITHOUT REPLACEMENT.

THE MEMBRANE BASICALLY IS A VERY, VERY FINE SCREEN OR SIEVE THAT SCREENS AT MOLECULAR LEVELS. IT HAS CAPACITY TO ENRICH A PROTEIN STREAM, LIKE MILK BY ALLOWING WATER, LACTOSE, SOLUBLE SALTS, AND NON-PROTEIN NITROGEN AS FREE AMINO ACIDS AND SMALL POLYMERS TO PASS THROUGH OR PERMEATE; WHILE RETAINING THE PROTEINS INCLUDING WHEY PROTEINS. A LIQUID STREAM ENRICHED IN PROTEINS, BUT STILL CONTAINING SOME LACTOSE, SOLUBLE SALTS, AND NON-PROTEIN NITROGEN AS FREE AMINO ACIDS AND SMALL POLYPEPTIDES IS CALLED CONCENTRATE OR RETENTATE. FOR EXAMPLE, MILK THAT HAS HALF OF ITS VOLUME REMOVED BY ULTRAFILTRATION HAS TWOFOLD INCREASE IN PROTEIN CONTENT AND APPROXIMATELY HALF OF ITS LACTOSE AND APPROXIMATELY HALF SOLUBLE SALTS AND OTHER SMALL MOLECULES REMOVED. THIS ULTRAFILTERED MILK BY VIRTUE OF HAVING HALF OF ITS VOLUME REMOVED, IS LESS EXPENSIVE TO TRANSPORT OR CAN BE TRANSPORTED TWICE THE DISTANCE FOR THE SAME COST, AND CAN BE USED FOR CHEESE MANUFACTURE. SINCE HALF OR MORE OF ITS VOLUME OF MILK HAS BEEN REMOVED, LOSS OF MILK COMPONENTS DURING CHEESE-MAKING IS REDUCED. THE ADVANTAGES TO THE CHEESE-MAKER THAT ULTRAFILTERED MILK PROVIDES INCLUDE MORE CHEESE MADE IN EXISTING EQUIPMENT, LESS RENNET

REQUIRED, LESS WHEY TO DISPOSE, AND POTENTIALLY MORE CHEESE YIELD. IN ULTRAFILTRATION, FAT DOES NOT PERMEATE, AND, THEREFORE, REMAINS WITH THE PROTEIN. SINCE CONSIDERABLE AMOUNT OF CALCIUM AND PHOSPHORUS IS BOUND OR TRAPPED IN THE PROTEIN, IT TOO REMAINS IN THE CONCENTRATE.

MILK CAN BE ULTRAFILTERED BEYOND THE HALF VOLUME LEVEL; CONCENTRATES HAVE BEEN MADE THAT HAVE BEEN ULTRAFILTERED TO THE COMPOSITION OF CHEESE. THESE CONCENTRATES HAVE BEEN CALLED PRECHEESE, SINCE THE COMPOSITION RESEMBLES THE COMPOSITION OF CHEESE. BY CULTURING THESE PRECHEESE CONCENTRATES WITH LACTIC CHEESE CULTURES AND USING RENNET, CHEESE CONSISTENCY CAN BE PRODUCED WITH ALMOST NO WHEY. CONVERSION OF PRECHEESE MILK CONCENTRATE INTO CHEESE, REQUIRES SPECIALIZED CHEESE PROCESSING EQUIPMENT AND LENDS ITSELF MORE TO A CONTINUOUS CHEESE-MAKING PROCESS. FOR MANY REASON, PRECHEESE MILK CONCENTRATE PRODUCED ANY PLACE OTHER THAN IN A CHEESE FACTORY PLANT, IS NOT ADVISABLE AT PRESENT.

PRODUCTION OF ULTRAFILTERED MILK BY REMOVING HALF OR THREE-QUARTERS OF THE VOLUME APPEARS TO BE FEASIBLE AT THE SOURCE OF MILK PRODUCTION.

THE NATIONAL STUDY ON MILK ULTRAFILTRATION WILL BE RUN ON ADAM VAN EXEL'S FARM WHICH IS LOCATED NEAR LODI,



CALIFORNIA. DR. ZALL WILL HEAD UP THE PROJECT. THE FOUR CHEESE PLANTS CHOSEN TO PRODUCE CHEESE FROM THE ULTRAFILTERED MILK ARE LOCATED AT SONOMA, CALIFORNIA WHICH WILL PRODUCE MONTEREY JACK, SECOND PLANT IS LOCATED AT TRACY, CALIFORNIA WHICH WILL PROCESS MOZZARELLA, THIRD PLANT IS LOCATED AT PETALUMA, CALIFORNIA WHICH WILL PRODUCE MONTEREY JACK AND CHEDDAR CHEESE THREE MONTHS OLD, THE FOURTH PLANT IS LOCATED AT ROW (WEST OF PETALUMA) WHICH WILL PRODUCE BRIE CHEESE. ADAM VAN EXEL IS A MEMBER OF THE CALIFORNIA COOPERATIVE CREAMERY.

MILK IN CONCENTRATE WILL BE MONITORED FOR: 1) STANDARD PLATE COUNT, 2) COLIFORMS, 3) MICROSCOPIC COUNTS, 4) ACID DEGREE VALUES, 5) PROTEIN, 6) FAT, 7) TOTAL SOLIDS, 8) ANTIBIOTICS, 9) FLAVOR, 10) NON-PROTEIN *Tyrosine* NITROGEN, 11) SOMATIC CELL COUNT, 12) ASH. MOST OF THESE ANALYSES WILL BE DONE WITHIN THE ON-SITE LABORATORY THAT IS ALREADY ESTABLISHED ON ADAM VAN EXEL'S FARM. THE MOST SOPHISTICATED ANALYSES WILL BE DONE AT MCKESSON ROBBINS LABORATORIES.

TO ALLOW ADAM VAN EXEL TO PROCESS MILK, THE ULTRAFILTRATION SECTION OF HIS MILK HOUSE WILL BE DECLARED A PROCESSING AREA; THEREFORE, HE WILL HAVE TO HAVE A PROCESSING LICENSE. THE REASON FOR THAT IS THAT CHEESE PROCESSING WOULD BE STARTED WITH ULTRAFILTRATION.

THE ULTRAFILTRATE WOULD BE TRANSPORTED UNDER THE CONTROL OF CALIFORNIA COOPERATIVE CREAMERY TO THE SELECTED PLANT FOR INCORPORATION OR PRODUCTION OF CHEESE.

CHEESE PROCESSING WOULD BE MONITORED FOR PH AND ACIDITY DURING CHEESE-MAKING ON CURD NOT WHEY. THE ACCELERATION OF ACIDITY WOULD BE INCREASE OR DECREASE OF STARTER AMOUNTS. CHEESE GRADING WILL BE DONE BY EXPERTS APPROPRIATE TO THE CHEESE VARIETY IN QUESTION. MOST LIKELY THESE EXPERTS WILL BE SELECTED FROM USDA PERSONNEL.

THE MEMBRANE PROCESS WILL BE EVALUATED FOR ENERGY DEMAND, LABOR REQUIREMENT, CLEANING COSTS, DURABILITY, WATER USE, WASTE AMOUNTS BEING GENERATED, SANITATION AND EFFICACY (TO MAKE SURE EVERYTHING IS CLEAN) SWAB TESTS WILL BE TAKEN.

IN ORDER OF INSURING SUCCESS, WE HAVE ESTABLISHED ADVISORY COMMITTEES TO GUIDE US ALONG:

ON-FARM ULTRAFILTRATION PROJECT COMMITTEES

- . CHEESE GRADING
- . CHEESE PRODUCTION
- . CHEMICAL, BIOLOGICAL, PHYSICAL STANDARDS
- . CULTURES
- . ECONOMICS
- . SAMPLING
- . ULTRAFILTRATION - THERMALIZATION

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THE ULTRAFILTRATION UNIT CHOSEN FOR THIS PROJECT WAS THE ALPHA DE LAVAL UNIT. THE REASONS IT WAS CHOSEN ARE: 1) BETTER EQUIPMENT FOR DAIRY FARM, 2) MORE

SUITABLE FOR FARM, 3) INVESTED INTEREST IN UF, 4) EXCELLENT ENGINEERING STAFF, 5) PRICE WAS ACCEPTABLE, 6) ANCILLARY EQUIPMENT ACCEPTABLE, 7) DRINC, CMAB, AND UF COMMITTEE MEMBERS' CHOICE, 8) CHEESE PRODUCTION EXPERIENCE VIA UF, 9) MARKETING NETWORKS SUPPORT, 10) SERVICE NETWORK SUPPORT. I WOULD LIKE TO ADD THAT THE INTENT WAS TO SELECT THREE DISSIMILAR UNITS AND PLACE THESE UNITS ON THREE FARMS IN CALIFORNIA FOR PROCESSING. UNFORTUNATELY, IT WAS NOT POSSIBLE TO GET THESE UNITS GRATIS. THEREFORE, THE CHOICE HAD TO BE MADE AND THE CHOICE WAS ALPHA DE LAVAL.

#### CHEESE GRADING

CHEESE WILL BE GRADED ACCORDING TO 1) PHYSICAL CHARACTERISTICS, 2) CHEMICAL CHARACTERISTICS, 3) QUALITY ASSURANCE.

##### 1. PHYSICAL CHARACTERISTICS

CHEESE SHOULD EXHIBIT AN ELECTRIC AND FUNCTIONAL CHARACTERISTICS TYPICAL OF THE VARIETY AND INDICATIVE OF ACCEPTABLE QUALITIES.

- 1) FLAVOR AND AROMA
- 2) BODY AND TEXTURE
- 3) APPEARANCE
- 4) FUNCTIONALITY--ITS SIGNIFICANT AND COMMERCIAL USE

## 2. CHEMICAL CHARACTERISTICS

CHEESE SHOULD EXHIBIT GROWTH, COMPOSITION IN NUTRITIONAL VALUE COMMENSURATE WITH STANDARDS OR ESTABLISHED VALUES FOR THE VARIETY:

### 1) GROSS COMPOSITION

A. MOISTURE

B. FAT

C. FDB

### 2) NUTRITIONAL CONTENTS

A. PROTEIN CONTENTS/PER (PER CALCULATED)

B. NUTRITIONAL EQUIVALENCE--ASSESSED AGAINST A CRITERIA SET FORTH 21CFR101.9

### 3) OTHER

A. SODIUM CONTENTS

## 3. QUALITY ASSURANCE

SAFETY AND WHOLESOMENESS OF CHEESE MUST BE ADEQUATELY ASSURED

1. SAFETY--RELATED GOOD MANUFACTURING PRACTICES

2. REGULATOR (FDA, USDA) ACCEPTANCE OF MEMBRANE FOR FOOD PROCESSING

# Properties of Products from Ultrafiltered Whole Milk

C.A. Ernstrom

Utah State University

Ultrafiltration (UF) of whole milk is being used increasingly as a first step in the manufacture of several cheese varieties. It may be considered part of the cheese making process because it actually substitutes for most of the curd syneresis responsible for whey separation in conventional cheese making. In this regard it does a better job of separation than syneresis because losses of fat and protein into the permeate are eliminated.

A brief review of ultrafiltration as applied to milk will lead to a better understanding of the kind and properties of products resulting from this process.

Most ultrafiltration membranes are synthetic polymers with differing degrees of porosity. The most common polymers are cellulose acetate, polysulfone and polyamide. Cellulose acetate membranes can be made with very low porosity and are commonly used for reverse osmosis where water removal is the main objective. They also are quite common in whey processing plants producing whey protein concentrates. Cellulose acetate membranes are susceptible to damage by heat, acids and alkalies. Therefore they operate best at temperatures below 100°F and between pH 5 and 8. They are not particularly suitable for milk processing since temperatures at which they operate favor rapid bacterial growth in the product. Strong acid and alkaline cleaning compounds cannot be used with these membranes.

Polysulfone and polyamide membranes are much more resistant to heat and strong cleaning compounds. Milk processing at 120-130°F is quite

common with these membranes. Cleaning solutions from pH 1 to 13 may be used with temperatures up to 176°F.

#### Separation of components in milk

During the ultrafiltration of milk the product moves across the surface of the membrane at a high velocity and under a pressure that may vary from 60-90 pounds per square inch on the inlet side to 15-30 psi at the outlet end.

Figure 1 is a schematic representation of the physical structure of milk during ultrafiltration. Only water and small dissolved molecules such as lactose, salt ions, and non protein nitrogen can pass through the membrane as permeate. Fat globules represented by the large spheres, casein micelles represented by the small spheres and soluble casein and whey proteins represented by the dash marks are retained by the membrane and concentrated in the retentate. In traditional cheese making the casein micelles form a clot in which they aggregate then stretch out into a three dimensional fibrous network in which the fat globules are physically trapped. The fibrous caseinate network then serves as a filtering device as the curd shrinks and expels whey. The caseinate network is more porous than UF membranes and allows the soluble whey proteins to escape into the whey along with about 7-10% of the fat. In other words the caseinate curd filtering membrane is less efficient in retaining protein and fat than commercial UF membranes.

The porosity of UF membranes may vary from less than 3000 to over 100,000 nominal molecular weight cut offs. This means that a membrane with a particular MW cut off will normally reject about 80% or molecules of particles with the specified molecular weight. Larger molecules are more and smaller ones are less completely rejected. For example, if a



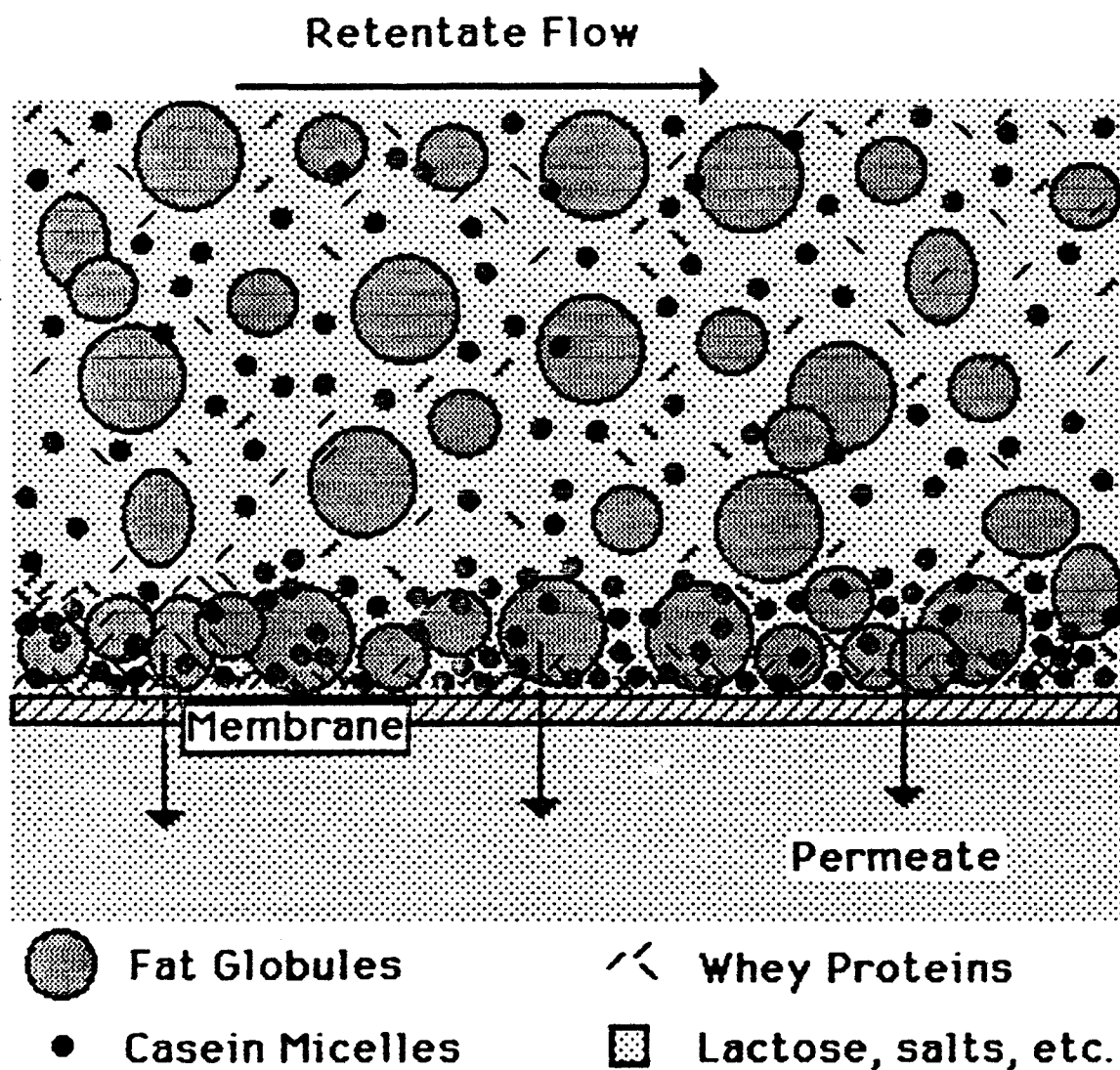


Figure 1. Schematic representation of separation of whole milk components by ultrafiltration.

membrane has a nominal molecular weight cut off of 25,000, about 80% of molecules with molecular weights of 25,000 will be held in the retentate and 20% could be expected to pass through the membrane into the permeate. The porosity of UF membranes is generally measured with dilute suspensions of neutral dextrans of known molecular weight ranges. This, however, does not mean that the molecular weights specified by membrane manufacturers will necessarily indicate their performance with milk. During ultrafiltration of milk a secondary membrane forms on the surface of the polymeric membrane. As illustrates in figure 1 this "secondary" membrane consists of packed caseinate micelles, fat globules and whey proteins which impact against the surface of the membrane. Some evidence points to the secondary membrane as the real filtering medium during the ultrafiltration of milk. If true, the nominal molecular weight cut off of the polymer membrane is not very critical for ultrafiltering milk. For example the permeate from a membrane with a 70,000 molecular weight cut off will allow the passage of some milk proteins into the permeate during the first few minutes of operation, but after the secondary membrane has formed the permeate becomes perfectly clear and separation seems to be as effective as with membranes of lower porosities. If the retentate stream moves across the surface of the membrane slowly the secondary membrane become thick and the flux rate, which is the rate at which permeate passes through the membrane, decreases. On the other hand if the velocity of the retentate is very high, shear forces of the moving stream keep the secondary membrane thin and the flux rate increases. Yan et al. (7) has demonstrated that high pressure in retentates favor a high flux rate in whole milk up to a point beyond which no further advantage is gained by

increasing pressures. Presumably this is because high permeation rates caused by pressure also favor a thickening of the secondary membrane which can be overcome only by further increasing velocity across the membrane surface. As the fat and proteins become more and more concentrated during ultrafiltration the retentate becomes more viscous which reduces the velocity of the retentate, increases the thickness of the secondary membrane and reduces the flux rate. One UF manufacturer they have been able to produce higher than usual concentrations by increasing the size of the channels and pumping the partially concentrated retentates with a second pump to maintain a high velocity in the retentate even with highly viscous concentrates.

#### Cheese Yields

One of the major advantages of using ultrafiltration for cheese making is improved yields that come from better recovery of fat and protein. In some cases substantially better yields have been realized. In others, no yield improvement has been experienced over traditional cheese making.

The difference boils down to the kind of cheese being made and the amount of syneresis that must take place in the cheese making process after ultrafiltration is complete.

When whole milk was reduced by ultrafiltration to one half its original volume (2X concentration) such as is being proposed for on-farm ultrafiltration, then made into Cheddar cheese in the conventional manner, Chapman et al (2) experienced no improvement in yield. This also has been the experience of others (1). Likewise UF skim milk concentrated by Matthews et al. (5) to 13% solids and made into cottage cheese did not result in improved yields.

In both of these instances a substantial amount of whey expulsion was still required in the cheese vat after ultrafiltration. The soluble whey proteins, even though concentrated during UF were expelled in a concentrated form into the whey during curd syneresis.

For example, if half as much whey is expelled during the syneresis of curd made from 2X concentrated milk as during the syneresis of non UF curd, but the concentration of soluble whey proteins is twice as great, the net effect on total protein recovery may be the same and no improvement in yield can be expected.

In the manufacture of Cheddar cheese curd for processing, milk is ultrafiltered to a 5X concentration, fermented and the final moisture removed by evaporation. There is no curd syneresis involved and yield increases of 16 to 18% over conventional Cheddar cheese processes have been reported (3). Likewise, when skim milk is ultrafiltered to a concentration of 16% total solids (9.3% protein), the curd must expell only a small amount of whey by syneresis and preliminary results suggests that yield increases of 10-12% might be possible.

Questions now are being raised about the fate of vitamins and minerals in milk during ultrafiltration. Data on these points are limited, but a recent publication by Green and associates (4) at NIRD in England indicate that those vitamins and minerals that are bound or partially bound to protein or fat globules are concentrated in the retentate and subsequent cheese curd. Those that are completely in solution freely pass through the membrane with the water. Their concentration in the retentate is in direct proportion to moisture retention. Green's membrane (4) was completely impermeable to fat, protein, vitamin B12 and folic acid in milk. Both vitamins B12 and

folic acid are tightly bound to milk proteins which accounts for their retention. Vitamin B6 and riboflavin were retained about 35 and 15% compared to fat and protein at 100%. These vitamins are partly bound to milk proteins.

Calcium, magnesium, zinc, iron, phosphorus and copper are partly associated with milk proteins and are concentrated in the retentate in proportion to the amount that is bound. For example about 60-70% of the calcium in milk exists as insoluble colloidal calcium phosphate associated with the casein micelles. Forty percent of the phosphorous and 100% of the zinc is similarly bound. Consequently these minerals are concentrated in the retentate along with proteins.

#### Acidification

During traditional cheese making, the acidity that develops from starter activity causes some of the insoluble calcium and phosphate to go into solution where it is lost in the whey. Because of differences in acidity there is much less calcium in cottage cheese curd than in Cheddar curd and more in cottage cheese whey than in Cheddar whey.

Some of the properties of cheese are associated with the amount of calcium retained in the curd. The physical changes of Cheddar cheese curd that develop during cheddaring are not only a reflection of the effect of pH on the properties of casein, but also are related closely to the removal of calcium from the casein as a result of acid development.

Process cheese food made from curd produced by ultrafiltration of sweet milk will not melt because its calcium concentration is much higher than in curd made by the traditional process. If, however milk is acidified to pH 5.8 prior to ultrafiltration, part of the calcium

phosphate associated with caseinate micelles goes into solution and is removed in the permeate.

The effect of the pH of milk prior to ultrafiltration on loss of calcium and subsequent meltability of process cheese products is very dramatic.

Figure 2 shows the relationship between pH of milk prior to ultrafiltration and the melting properties of pasteurized process cheese food made from the curd. In this case about 70% of the original milk calcium was removed from the curd during ultrafiltration and diafiltration at pH 5.8 while only 53% was removed during ultrafiltration and diafiltration when the milk was at pH 6.6.

When the insoluble calcium phosphate associated with casein micelles is partially removed by acidification the physical structure of the micelle changes and the properties of the casein are also altered by the acid. The net effect is that the nature of the proteinaceous material in the secondary ultrafiltration membrane is changed in a way that reduces its porosity. Figure 3 shows the effect of pH of the milk on the flux rate during ultrafiltration and diafiltration. Note that as the pH of the milk decreased from 6.6 to 5.8, the initial flux rate decreased from 55 to 23 liters/m<sup>2</sup>/hour at a temperature of 130°F.

Green, et al (4) reported that acidification of milk to pH 6.0 caused a dissociation of some of the vitamin B12 and folic acid from the milk proteins which resulted in partial loss of these vitamins into the permeate.

#### Diafiltration

Ultrafiltration of milk during cheese manufacture generally leaves too much lactose in the retentate, the complete fermentation of which

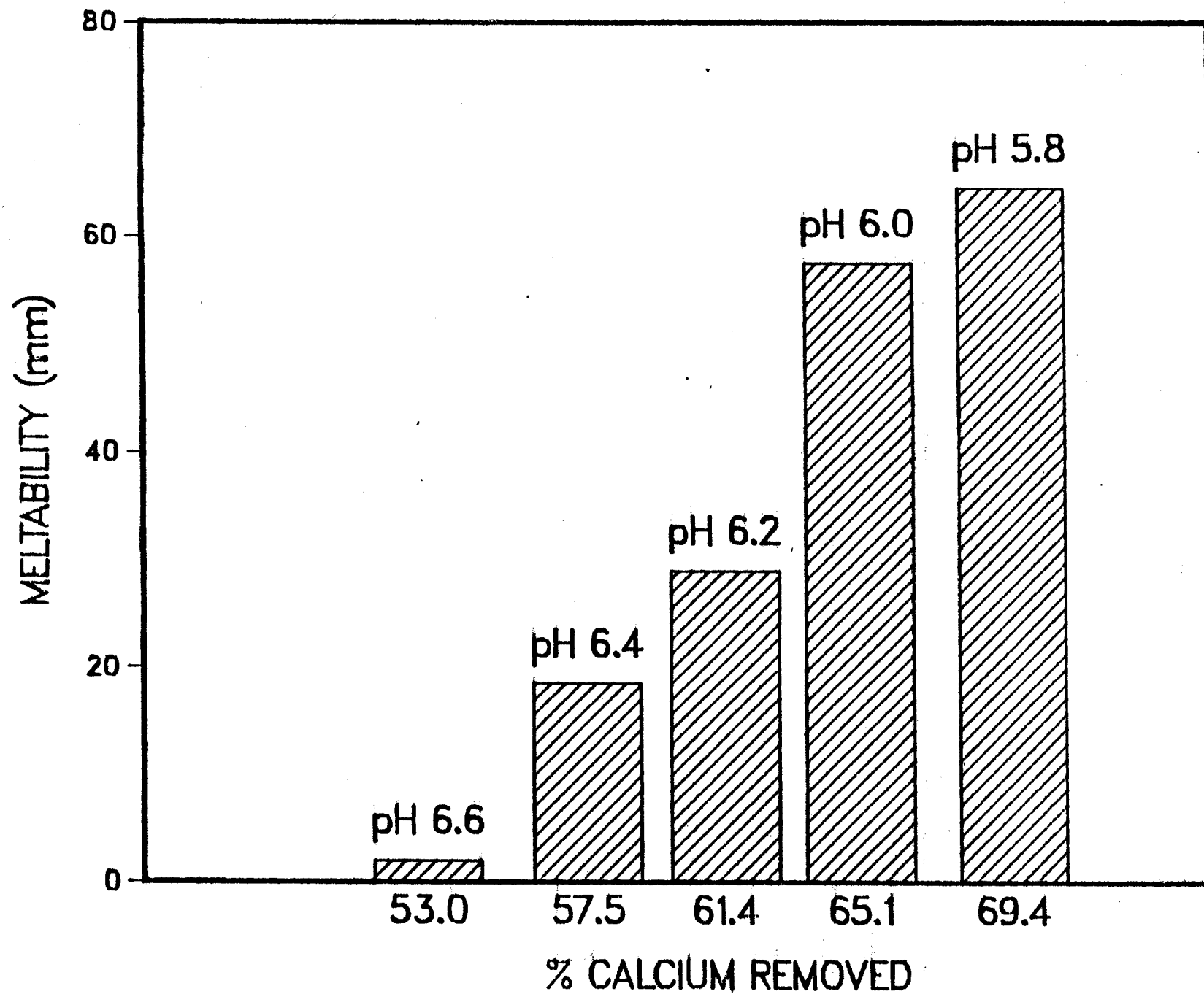


Figure 2

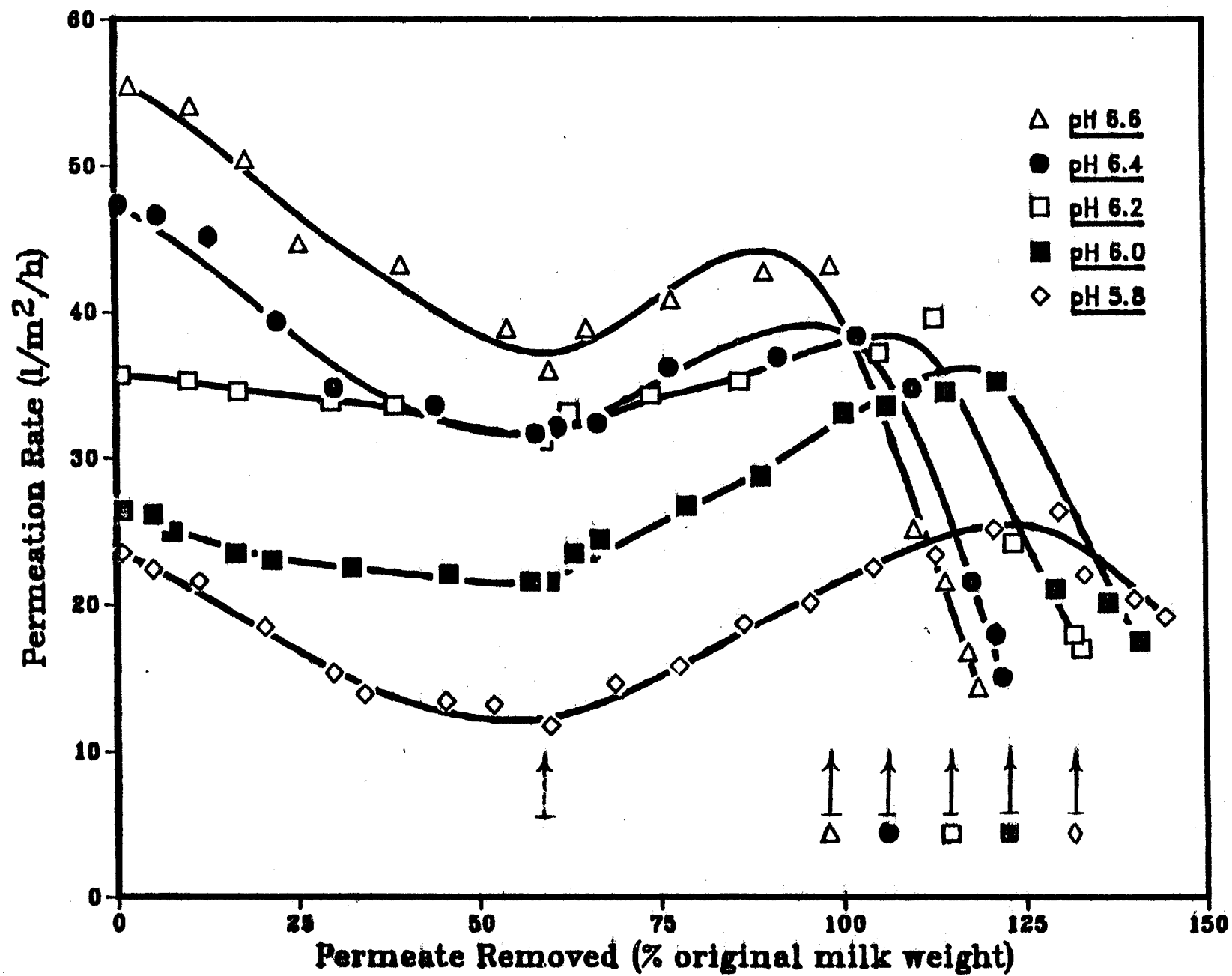


Figure 3



would make some kinds of cheese much too acid. This problem is easily corrected by the introduction of water into the retentate at an appropriate point during ultrafiltration. This process called "diafiltration" serves to wash out additional lactose and other small molecules. The final acidity of any cheese product can be accurately controlled by the amount of lactose removed from the retentate by diafiltration. Diafiltration at constant volume requires the least amount of water. In this procedure water enters the feed system at the same rate permeate is removed.

#### Heat Treatment of Retentates

Recent attempts have been made to use ultrafiltration to produce a soft white cheese similar to Caso Blanco varieties consumed by the increasing latin American population in the U.S.

Milk subjected to high heat treatments (175°-30 min) will not coagulate with rennet, but Maubois and Mocqust (6) reported that heat treated milk that is subsequently concentrated by ultrafiltration will coagulate and form a good curd. We were interested in the effects of heat treatment on the retentate instead of the milk.

Fresh whole cows milk containing 3.7% fat and 12.95% total solids was pasteurized at 63°C for 30 minutes, cooled to 54°C and ultrafiltered until 60% of the original milk weight had been removed as permeate. The retentate was then diafiltered at constant volume by bleeding 54°C deionized water into the supply tank at the same rate permeate was being removed until an amount of water equal to 38.5% of the original milk weight had been added. At that point the diafiltration water was turned off and ultrafiltration was continued to a 5X concentration.

Preliminary experiments in which the retentate was inoculated with lactic culture and set with rennet resulted in cheese with an appropriate pH of 5.15 but which continued to expell whey and was considered very mealy and spongy.

Similar retentate was then divided into five parts and heated for 30 minutes at 150, 160, 170, 180 and 190°F before cooling to 70°F and inoculating with 1% lactic culture. Retentate representing each heat treatment was divided into two lots. To one lot was added 2.5% salt, renneted (3 ml/100 lb) and sealed in cans. The other lot was renneted and placed in cans with a circle of parchment under the lid. Salt equal to 2.5% of the retentate was placed on the parchment under the lid. This was to delay the absorption of the salt into the cheese until the starter had had a chance to reduce the pH.

All cans were incubated upside down at 22°C for 1 day then turned right side up and incubated for an additional day.

The effect of salting method on rate of pH change is shown in figure 4 for the sample heated to 82.2°C and was typical of all other treatments. Direct salting slowed the pH change although it eventually reached pH 5.1 after 15 days. When salt penetration was retarded by parchment the pH reached 5.4 in one day and 5.15 in 3 days.

Of greatest interest in this study was in the effect of heat treatment of the retentate on the mealiness of the final product. This is illustrated in figure 5. A panel of four judges rated mealiness on a scale of 0 (no mealiness) to 4 (very mealy). As the heat treatment increased the tendency toward mealiness decreased. Furthermore the tendency for whey expulsion also decreased.

Fig. 8

Slide 8: Effect of salting method of the pH of Domiati cheese made from ultrafiltered whole milk and stored for one month at 22°C.

Storage (Days)	Retentate heat treatment: 82.2°C/30 min			
	D		P	
	pH	SD	pH	SD
0	6.68 ± .02		6.64 ± .01	
1	6.10 ± .04		5.40 ± .02	
2	5.80 ± .08		5.30 ± .04	
3	5.50 ± .06		5.15 ± .04	
15	5.25 ± .04		5.05 ± .02	
30	5.10 ± .05		5.05 ± .02	

D = 2.5% salt dissolved in the retentate before renneting.

P = 2.5% salt dispensed in cheese through parchment paper.

FIG. 5

~~Slide 9:~~ Effect of retentate heat treatment and salting method on the mealiness\* of Domiati cheese made from ultrafiltered whole milk.

	<del>150°F</del> 65.5°C/30min.		<del>160°F</del> 71.1°C/30min.		<del>170°F</del> 76.6°C/30min.		<del>180°F</del> 82.2°C/30min.		<del>190°F</del> 87.7°C/30min.	
	D	P	D	P	D	P	D	P	D	P
Max.	4	4	4	4	3	3	3	3	2	1
Min.	4	3	3	2	2	1	2	0	0	0
Av. Score	4.0	3.8	3.4	3.0	2.6	2.4	2.4	1.0	1.0	0.2
SD	±0.00	±0.45	±0.55	±0.71	±0.55	±0.89	±0.55	±1.41	±0.71	±0.45

D = 2.5% salt dissolved in the retentate before renneting.

P = 2.5% salt dispensed in cheese through parchment paper.

\*Mealiness score: 4 - very mealy, 0 - no mealiness

It was concluded that a cheese similar to Caso Blanco, but with controlled pH, and extended shelf life can be made from ultrafiltered whole milk by heating the retentate to at least 180°F for 30 min prior to culturing and setting.

A preliminary experiment investigated the effect of heating the milk prior to ultrafiltration rather than heating only the retentate. In this instance it was impossible to reduce the moisture in the retentate below 68%. At that point all permeation stopped.

Heat treating retentate offers some interesting possibilities for new products since acid development and coagulation can take place in the final retail package. A variety of flavoring materials may be added to the liquid retentate before setting, and there is little if any syneresis or whey drainage during storage.

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Utah State University  
6th Biennial Cheese Industry Conference  
Logan, Utah  
August 28-30, 1984

"A NEW ENZYME REACTOR SYSTEM FOR HYDROLYZING LACTOSE  
IN WHEY PERMEATE AND MILK PERMEATE"  
Bruce S. Goldberg  
Amerace Corporation - Technical Center  
State Highway 24  
Hackettstown, NJ 07840

## INTRODUCTION:

There was approximately 5.4 billion pounds a year of cheese produced in the US in 1983. The industry has a tremendous volume of whey to handle when one considers that for every 10 pounds of milk used to produce a pound of cheese, there is also 9 pounds of whey produced or about 48 billion pounds per year. Approximately half of this whey is presently disposed of as a waste stream. The other half is dried in some cases to produce whey powder, delactosed to produce lactose and whey, evaporated to produce a syrup or fractionated via ultrafiltration to produce whey protein concentrate and permeate.

The permeate is a watery solution that contains the milk salts and lactose. If ultrafiltered milk is used to produce cheese, it too produces a milk permeate stream similar to the whey permeate stream. One asks the question, "what do you do with the permeate?" In some cases it is discarded as a waste stream and in others it may be concentrated and dried and used as an animal feed or fermentation media. We propose that it be hydrolyzed to produce a sweetener substitute, fermentation media or chemical feedstock.

Amerace Corporation has developed an immobilized enzyme technology that allows us to hydrolyze lactose or lactose in whey or milk permeate into glucose and galactose. This process and the marketing of it has been licensed to the Damrow Company of Fond du Lac, Wisconsin and is marketed under the Damrace name. Our objective today is to discuss this process with you.



### Enzyme Support Material

Many of you are familiar with the use of the enzyme such as Rennet to produce cheese or lactase to hydrolyze milk, whey or permeate by a batch process. The process that will be discussed today is a continuous process based on an immobilized lactase enzyme. The immobilized enzyme route helps to reduce cost as the enzyme is used many times before it is discarded and does not remain with the finished product.

The enzyme must be bound to a support and Amerace uses a microporous plastic sheet that it produces. Most past immobilized enzyme systems made use of either packed columns filled with organic or inorganic support material or used ultrafiltration devices where the enzyme was separated from the feedstock across the membranes. The feedstock containing a material of lower molecular weight would diffuse through the membrane, react with the enzyme and then diffuse back out through the membrane.

The major disadvantage of the bed systems lies in the fact that the enzyme is usually bound inside the bead, which reduces its efficiency since the substrate (feed) must diffuse into the bead to react with the enzyme and then diffuse back out again. This reduces the reaction rate. Beds are noted for uneven liquid distribution which results in channeling and again less efficient use of the enzyme. Since packed columns are made up of bead type materials, they offer a handling problem on filling and discharging the column.

The Amerace System uses microporous plastic sheets that are about 20 thousandths of an inch thick, made of PVC and silica. These sheets

are about 80% porous and have a very large surface area. Therefore, large quantities of enzyme can be chemically loaded onto the sheet. The enzyme is bound to the outside of the silica and the substrate (feed) comes into intimate contact with it without the diffusion problems that exist in bed systems. This results in high utilization of enzyme, faster reactions and smaller reactors. The microporous plastic sheets are stacked upon each other to form a module. The modules are much easier to handle as compared to pellets or powders in a packed column system. (Figure 1 illustrates the above phenomena.)

The thickness of the module is a function of the reaction kinetics. The kinetics determine what the residence time must be for the reaction to proceed at a fixed set of conditions of temperature, pH and concentration. Modules are placed between support or feed plates (see Figure 2) and then placed in a reactor press. The modules are placed in series in the press and the flow is in parallel into each module. If production is increased, more modules can be added and if production is reduced, a certain number of modules can be removed. As you can appreciate, the handling is much easier than components used in bed systems.

#### The Effect Of Lactose Concentration

One parameter that is important from a reactor design standpoint is the concentration of lactose in the feed. As you can see from Figure 3, a 5% feed requires 1.5 minutes residence time in the reactor to achieve 90% hydrolysis of the lactose and only 42 and 24 seconds to achieve 80 & 75% hydrolysis respectively. If one increases the feed to 10%, the residence times increase to 4.5, 2.0 & 1.4 minutes

respectively. One notes that as the feed solids increases, the reaction rate slows down. Therefore, from a reaction standpoint, a 5% lactose concentration gives the higher rate but even 15% concentrations are feasible but not as economical since a large reactor is involved. However, the higher reactor economics may be offset by the potential savings in steam in removing less water on evaporation.

### Pilot Reactor

The Damrace hydrolysis process was scaled up from the lab to a pilot system. Where the lab unit uses a module that is about 2 inches in diameter, a pilot unit uses a module 12 inches in diameter. The pilot plant allowed us to finalize our engineering design for a commercial unit and at the same time was used for customers to try out their feedstocks. Pilot plants are now available from Damrow for the industry to evaluate the process in their plants and to produce products that can be used for market development activities.

The following (Figure 4), is a schematic of the Damrace process as used in a pilot plant. The permeate is first ultrafiltered polished. The reason for this is that permeate from one commercial plant to another varies considerably in their quality due to the residual protein in it. The reason for the various quality levels of commercial permeate is due to how efficiently the operation is run. In some cases, membrane sealing can be a problem, in others as the membranes age, one gets bleed through of protein and in others, membranes crack. In order to be assured of a consistent quality feedstock to our reactors, we polish ultrafilter the permeate to remove the traces of protein, bacteria, etc. that may be in it. This

UF unit is an order of magnitude smaller than the UF system used in the protein plants since the quantity of protein to be removed is very small. This results in very high fluxes which lead to small surface areas in the UF units.

The ultrafiltered polished permeate is then passed through an on line turbidity meter to monitor, the clarity of the feed and to make sure it is in spec. This assures us that the reactor will have a consistent feedstock and that the product produced will always be of consistent quality free of protein. The feed then passes to a hold tank where its pH is adjusted to 4.5 and then through an inline ultraviolet unit (UV) to reduce the tendency of bacterial growth. A portion of the UV treated feed is recycled back to the feedtank and a portion is fed to the reactor. We have found that with clear feedstocks, the UV unit does a good job in reducing bacterial growth. The feed then passes through a heat exchanger to be either heated or cooled to the reaction temperature. It then passes through a 2 micron cartridge filter to remove any suspended matter and then through a 0.45 micron filter to remove anything that passes through the 2 micron unit. Our experience has been that the 2 micron filter takes everything out and the 0.45 acts as an insurance policy. The 2 micron filter can be cleaned and reused for a few days. The 0.45 micron can be cleaned and reused as long as the reactor modules are still active. For the pilot unit, this is about 2000 hours, and for the commercial unit, about 5000 hours.

The feed's pH is checked once again before it enters the reactor. The feed to the reactor comes into a common header and branches off into

parallel streams, such that each module gets the same equal flow. You will note that the modules are in a press and in series but the liquid flow to each is in parallel. The exit flow from each module goes into a header that takes the hydolyzed product away.

### System Cleaning

A shut off valve exists before the reactor to isolate it for cleaning. When this valve is closed, one cleans all the hardware. The equipment before the reactor is cleaned by the standard cleaning in place process (CIP) using alkali, acid and bleach. One cannot use these solutions to clean the reactor modules because they will kill the enzyme. While the front end of the hardware is being cleaned, the reactor modules and reactor are cleaned with a buffer solution of sodium acetate containing a bacteriacide. This solution cleans the modules and reduces the potential for bacteria growth. If one wanted to do further cleaning, once a week for instance, one can take the buffered modules out, place them in a refrigerator, close the press up and clean it in place with the normal CIP procedure.

A typical pilot reactor press is about 8 feet long by 11 feet wide and is capable of handling up to 3gpm of a 5% feed, 2.0gpm for a 10% feed and 1.5gpm for a 15% lactose feed concentration. Since we have standardized on a pilot press length, only for the pilot plant, one does not get equal maximum flow for each feed concentration because the module thicknesses are different. A 5% feed requires only a 0.7" thick module. As you can see, a relatively small area is required on a pilot basis to produce a significant amount of product.

### Commercial System

Since the modular design of the flow through reactor is directly scaled up, the data obtained on a 2" diameter lab unit or a 12" pilot unit will be valid for the 29" diameter commercial module. A commercial plant would be very similar to the pilot plant except it would have more automated controls. The reactor press size for a commercial plant may be 12 feet long by about 3 feet wide. Depending on capacity, one would have a number of them in parallel.

It is estimated that the hardware cost for a complete Damrace hydrolysis system to handle a one million pound/day wet permeate stream at 5% solids would be in the range of \$900,000. The immobilized enzyme module cost would be around \$200,000 and would last 5,000 hours at the exposed temperature of 30 degrees C. A total processing cost, including 10 year depreciation and immobilized enzyme module replacements, would be around 3.0 cents /lb. total solids. If evaporation, and/or demineralization are required, the total cost will increase. Evaporation to 70% would be about 2-2.5 cents/lb. direct operating cost without depreciation, and ion exchange another 3 cents/lb. Therefore, total syrup cost is about 8-9 cents/lb. total solids.

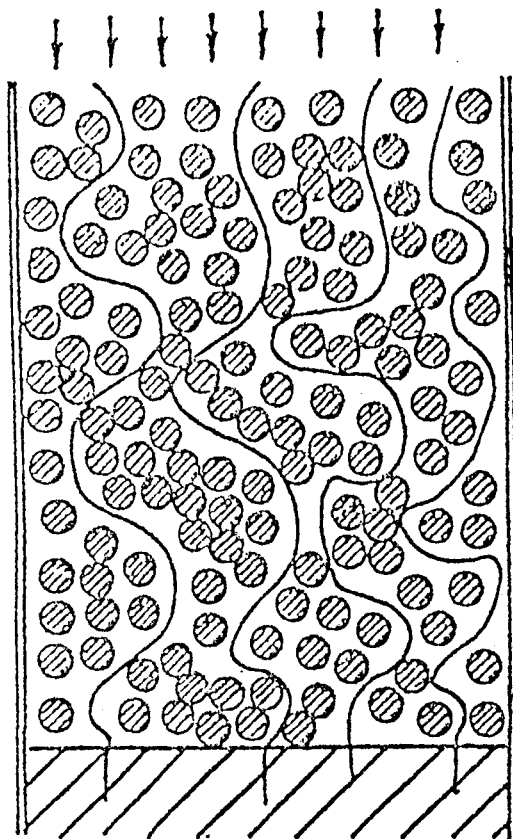
One can now have an economical process to hydrolyze lactose as-is or in permeate to glucose and galactose. The potential exists to convert what was a waste stream into a partial sweetener replacer at a lower cost than sucrose or high fructose, as a more efficient fermentation media than lactose, whey or molasses or as a possible carbohydrate raw material chemical feedstock. In some cases, demineralization would be

required and in others it would not be required.

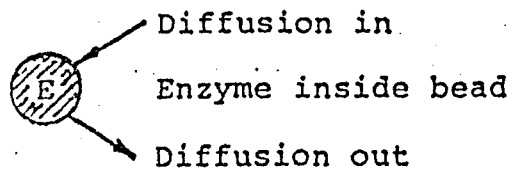
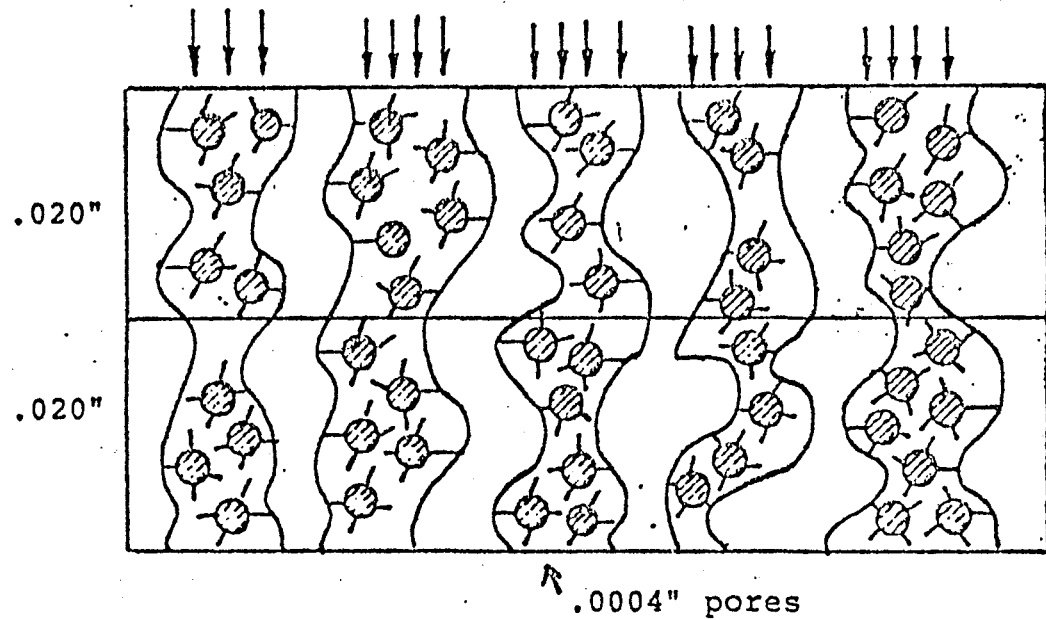
The Damrace System is now available through the Damrow Company for piloting or commercializing a hydrolyzed permeate process.

REACTOR CONCEPTS

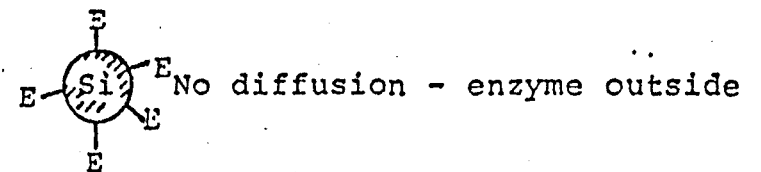
BED



AMERACE



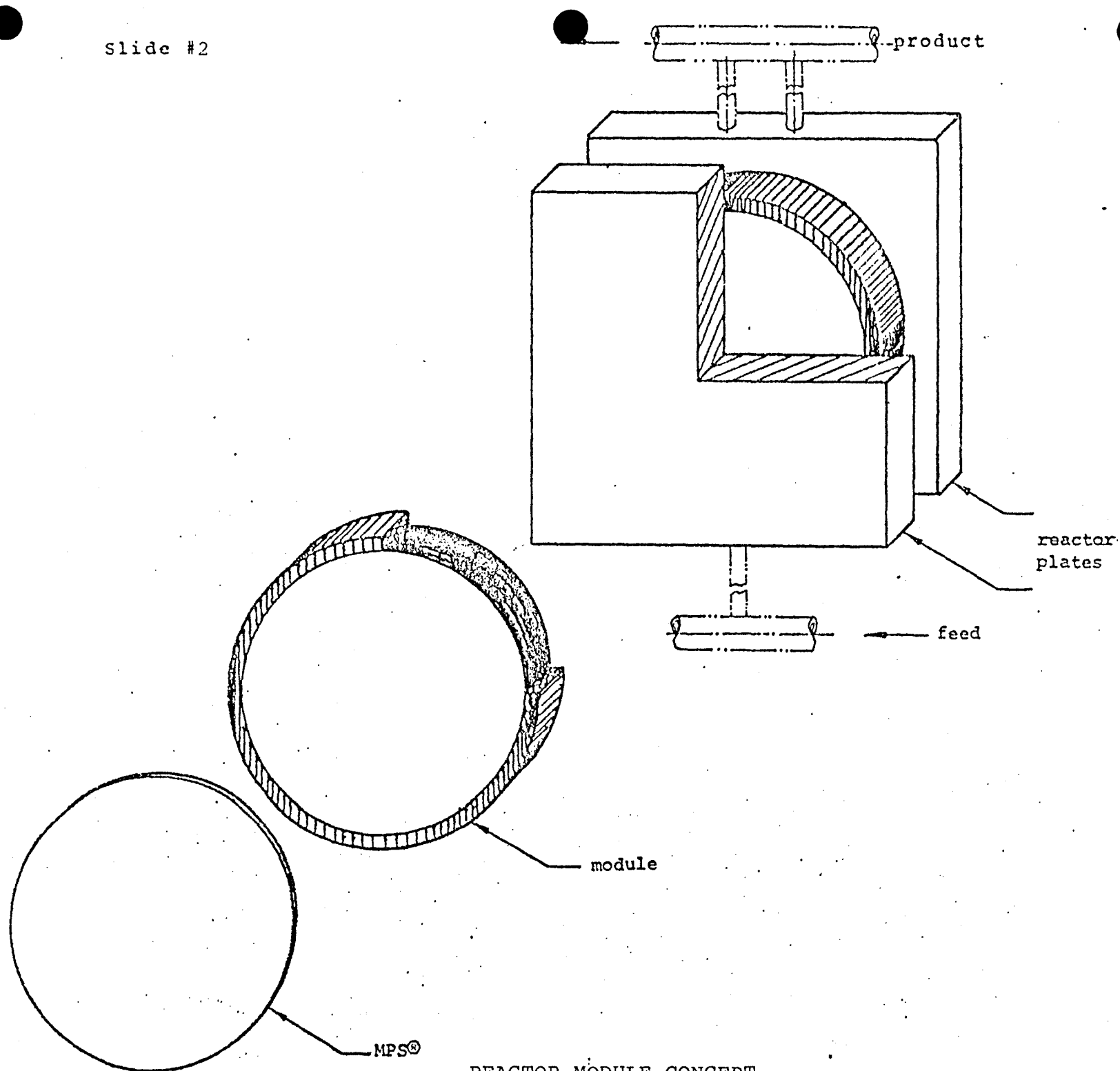
Powders - pellet handling



Modular



slide #2

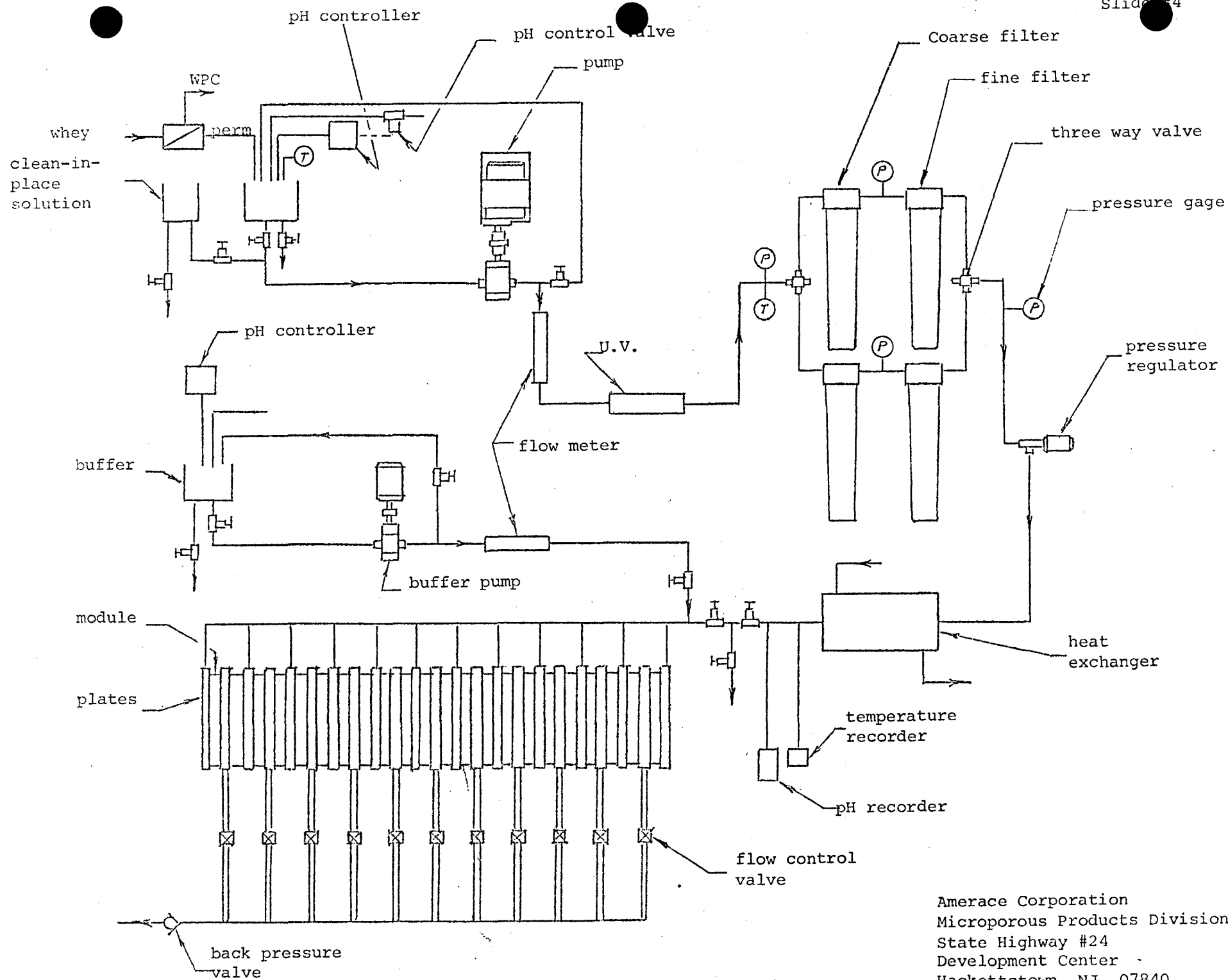


REACTOR MODULE CONCEPT

SLIDE #3

RESIDENCE TIME VS. SOLIDS AT 90%, 80%, 75% CONVERSIONS

<u>% Solids</u>	90% Conversion	80% Conversion	75% Conversion
	<u>Residence Time</u> min.	<u>Residence Time</u> min.	<u>Residence Time</u> min.
5	1.5	0.7	0.4
10	4.5	2.0	1.4
15	7.8	4.0	2.2
20	15.0	7.0	4.0
25	20.6	11.0	7.4
30	32.0+	13.6	10.0



PILOT OR COMMERCIAL REACTOR SYSTEM

Amerace Corporation  
 Microporous Products Division  
 State Highway #24  
 Development Center  
 Hackettstown, NJ 07840

## Comparison of End Product and Component Pricing Proposals for Cheese Milk

Rodney J. Brown  
Department of Nutrition and Food Sciences  
Utah State University

Both per capita and total consumption of cheese in the U.S. has been steadily increasing for the past twenty years (Figures 1 and 2). The rate of increase has accelerated in recent years (1). This dramatic shift in utilization of milk has generated interest in milk

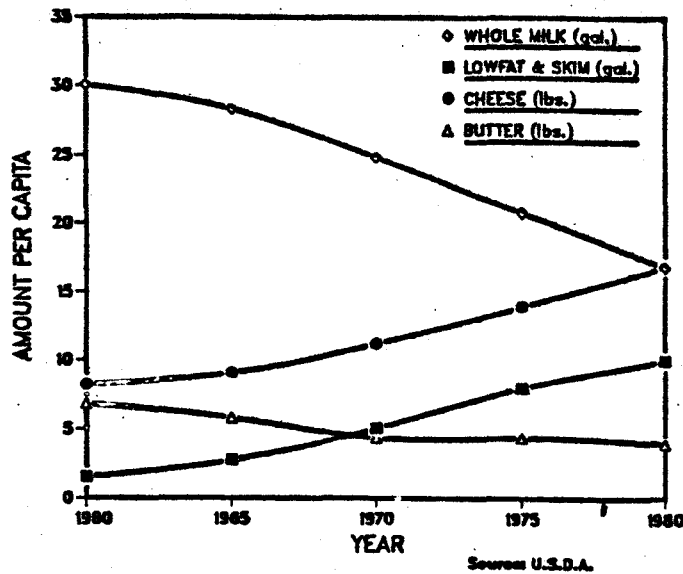


Figure 1. Per capita sales of dairy products in the U.S.

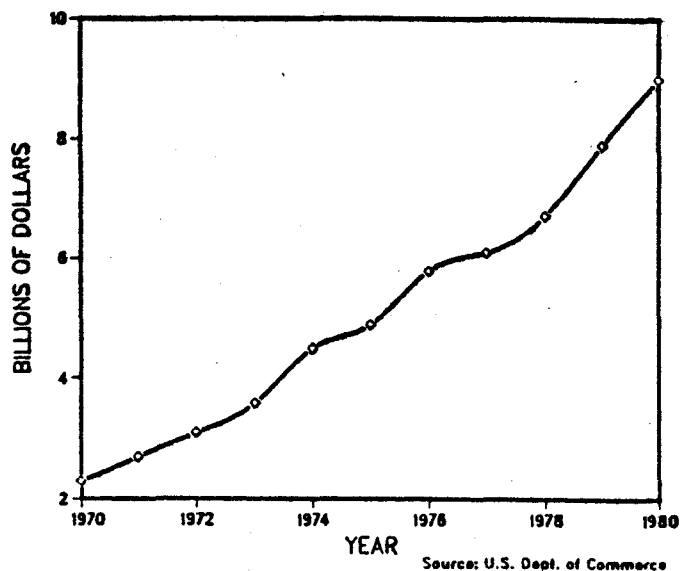


Figure 2. Cheese sales in the U.S.

payment programs that recognize the value of those milk constituents which contribute to cheese yield. The urgency to do something, because of fear that the milk supply would disappear if something was not done quickly, has induced some to adopt new payment programs before taking time to examine their consequences to cheese plant profitability. This paper will compare some of the most prominent methods of payment in light of their effects on the profitability of a cheese plant.

Table 1 lists twenty one milk samples which were randomly selected over one year from pooled herd milk. These samples represent the variability which is found in milk purchased from different farms. It should be of interest to cheese makers that even though the casein:fat ratio averages .68 it varies from .59 to .96. Fat was removed to bring the casein:fat ratio up to .64 then

Table 1. Randomly selected milk samples used as examples. Milk was standardized to .64 casein:fat by removal of extra fat before calculating yield of 38% moisture Cheddar cheese. Casein was estimated as 78% of total protein.

Sample	% Fat	% SNF	% Protein	C/F	Lbs Extra Fat	Lbs Cheese
1	2.60	8.88	3.20	.96		8.46
2	3.17	8.88	3.33	.82		9.57
3	3.57	8.84	3.33	.73		10.23
4	3.72	8.64	3.19	.67		10.28
5	3.60	8.76	3.42	.74		10.40
6	3.72	8.86	3.32	.70		10.46
7	3.72	8.78	3.34	.70		10.49
8	3.68	8.94	3.49	.74		10.63
9	3.94	8.81	3.32	.66		10.82
10	3.82	8.92	3.49	.71		10.86
11	3.96	8.74	3.38	.67		10.93
12	4.67	9.18	3.70	.62	.16	12.27
13	4.72	9.39	3.86	.64	.02	12.81
14	4.75	9.43	4.07	.67		13.17
15	4.93	9.42	4.01	.63	.04	13.31
16	5.17	9.40	3.88	.59	.44	12.88
17	5.14	9.50	3.97	.60	.30	13.18
18	5.12	9.57	4.03	.61	.21	13.38
19	5.18	9.47	4.08	.61	.21	13.55
20	5.29	9.69	4.29	.63	.06	14.26
21	5.44	9.63	4.21	.60	.31	13.99
Ave.	4.28	9.13	3.66	.68	.08	11.71

Most fluid milk in the U.S. is paid for using a base price and fat differential system. Table 2 shows how this method would pay for the example milk from Table 1. To understand this method of payment it is helpful to know its history. When testing for fat became possible milk payment was changed from a volume basis to a fat basis. This was when butter was the most valuable dairy product. Milk was skimmed on the farm and the cream was sold to a creamery. The skim milk was most often fed to pigs on the farm.

Table 2. Base price and fat differential prices calculated for samples in Table 1. Base price for 3.5% fat milk was \$12.800 and fat differential was \$.170.

[illegible]

This system has been very useful for the fluid milk industry. It encourages farmers to produce large volumes of low solids milk by paying a premium for such milk. Unfortunately, this is not the kind of milk sought by cheese makers. The last column of Table 2 shows its disadvantage for cheese makers. As solids increase, as indicated also by an increase in cheese yield, the cost of enough

[illegible]

The base price and fat differential payment method has been modified by addition of a protein bonus to try to overcome the disproportionate payment for milk. Table 3 is the same as Table 2, but a bonus of \$.02 has been added for each tenth of a percent of protein above 3.5%. As can be seen in the last column, the protein bonus does not make much difference. The range of costs for enough milk to make a pound of cheese varies from \$1.12 to \$1.33 with the

[illegible]



Table 5. Fat and solids-not-fat prices calculated for samples in Table 1. Fat was valued at \$1.700 per pound and solids-not-fat were valued at \$.750 per pound.

Sample	% Fat	% SNF	% Protein	C/F	Lbs Extra Fat	Lbs Cheese	\$ Fat	\$ SNF	Fat/SNF Milk Price	Milk cost per Pound Cheese
1	2.60	8.88	3.20	.96		8.46	\$4.42	\$6.66	\$11.08	\$1.31
2	3.17	8.88	3.33	.82		9.57	\$5.39	\$6.66	\$12.05	\$1.26
3	3.57	8.84	3.33	.73		10.23	\$6.07	\$6.63	\$12.70	\$1.24
4	3.72	8.64	3.19	.67		10.28	\$6.32	\$6.48	\$12.80	\$1.25
5	3.60	8.76	3.42	.74		10.40	\$6.12	\$6.57	\$12.69	\$1.22
6	3.72	8.86	3.32	.70		10.46	\$6.32	\$6.64	\$12.97	\$1.24
7	3.72	8.78	3.34	.70		10.49	\$6.32	\$6.58	\$12.91	\$1.23
8	3.68	8.94	3.49	.74		10.63	\$6.26	\$6.71	\$12.96	\$1.22
9	3.94	8.81	3.32	.66		10.82	\$6.70	\$6.61	\$13.31	\$1.23
10	3.82	8.92	3.49	.71		10.86	\$6.49	\$6.69	\$13.18	\$1.21
11	3.96	8.74	3.38	.67		10.93	\$6.73	\$6.55	\$13.29	\$1.22
12	4.67	9.18	3.70	.62	.16	12.27	\$7.94	\$6.88	\$14.82	\$1.19
13	4.72	9.39	3.86	.64	.02	12.81	\$8.02	\$7.04	\$15.07	\$1.17
14	4.75	9.43	4.07	.67		13.17	\$8.07	\$7.07	\$15.15	\$1.15
15	4.93	9.42	4.01	.63	.04	13.31	\$8.38	\$7.06	\$15.45	\$1.15
16	5.17	9.40	3.88	.59	.44	12.88	\$8.79	\$7.05	\$15.84	\$1.17
17	5.14	9.50	3.97	.60	.30	13.18	\$8.74	\$7.12	\$15.86	\$1.16
18	5.12	9.57	4.03	.61	.21	13.38	\$8.70	\$7.18	\$15.88	\$1.16
19	5.18	9.47	4.08	.61	.21	13.55	\$8.81	\$7.10	\$15.91	\$1.15
20	5.29	9.69	4.29	.63	.06	14.26	\$8.99	\$7.27	\$16.26	\$1.13
21	5.44	9.63	4.21	.60	.31	13.99	\$9.25	\$7.22	\$16.47	\$1.14
Min.									\$11.08	\$1.31
Max.									\$16.47	\$1.31
Ave.									\$14.13	\$1.20

protein bonus instead of \$1.10 to \$1.33 without the bonus. The maximum price paid for milk increased from \$16.10 to \$17.12, but the lower price stayed the same at \$11.27. This is because there is no deduction for low protein milk but there is a bonus for high protein milk. That is why the average price is higher for this plan than for the base price and fat differential program alone.

Another variation of the base price and differential system is a base price with fat and protein differentials. This is shown in Table 4. The base price and fat differential are the same as in Table 2 and the protein differential was selected to make the average price per hundred pounds of milk the same as in Table 2. The maximum cost of \$1.49 for enough low solids milk to make one pound of cheese is higher than any of the other payment programs. One interesting feature of this payment scheme is that both low and high solids milk is encouraged, with a valley in the middle.

A variation of the fat and solids-not-fat system is a fat and protein system (Table 6). Variation in the milk cost per pound of

[illegible]

A payment system for cheese milk called cheese-yield-pricing was presented at this meeting four years ago (1). Since that time it has also been called end-product-pricing. Table 7 shows how this pricing system works with the milk samples from Table 1. The amount of extra fat (removed to standardize to casein:fat of .64) is multiplied by an extra fat value of \$1.700. The amount of cheese is multiplied by a cheese yield value of \$1.194. These two values are added together to find the price per hundred pounds of milk.

[illegible]

There are other methods for milk payment, but most fall into one of the categories discussed here. Table 8 is a summary of the methods in Tables 2 through 7. The payment system which least closely corresponds to the value of milk for cheese making is a base price system with both fat and protein differentials. Base price with a fat differential is next. A protein bonus added to the base price and fat differential has very little effect, but does raise the total cost of milk procurement. Payment for pounds of fat and solids-not-fat is next, but is still far from being linked to cheese yielding potential of the milk. If payment for pounds of fat and protein could be done with fat price, proteins price and proportion of fat and protein in cheese perfectly balanced it would be ideal. That is what cheese-yield-pricing does, but the necessity of determining separate values for fat and protein is eliminated. The cheese-yield-value is fixed at the allowable milk cost per pound of

Table 8. Comparison of milk from Table 1 as prices in Tables 2-7.

Milk Cost per Pound of Cheese									
Sample	% Fat	% SNF	% Protein	Cheese Yield	Fat Differ.	Fat/SNF	Fat/Prot. Differ.	Fat/Prot.	Protein Bonus
1	2.60	8.88	3.20	\$1.19	\$1.33	\$1.31	\$1.49	\$1.23	\$1.33
2	3.17	8.88	3.33	\$1.19	\$1.28	\$1.26	\$1.32	\$1.21	\$1.28
3	3.57	8.84	3.33	\$1.19	\$1.26	\$1.24	\$1.25	\$1.20	\$1.26
4	3.72	8.64	3.19	\$1.19	\$1.28	\$1.25	\$1.25	\$1.20	\$1.28
5	3.60	8.76	3.42	\$1.19	\$1.25	\$1.22	\$1.24	\$1.20	\$1.25
6	3.72	8.86	3.32	\$1.19	\$1.26	\$1.24	\$1.23	\$1.20	\$1.26
7	3.72	8.78	3.34	\$1.19	\$1.26	\$1.23	\$1.23	\$1.20	\$1.26
8	3.68	8.94	3.49	\$1.19	\$1.23	\$1.22	\$1.22	\$1.20	\$1.23
9	3.94	8.81	3.32	\$1.19	\$1.25	\$1.23	\$1.20	\$1.19	\$1.25
10	3.82	8.92	3.49	\$1.19	\$1.23	\$1.21	\$1.20	\$1.20	\$1.23
11	3.96	8.74	3.38	\$1.19	\$1.24	\$1.22	\$1.19	\$1.19	\$1.24
12	4.67	9.18	3.70	\$1.19	\$1.18	\$1.19	\$1.13	\$1.19	\$1.19
13	4.72	9.39	3.86	\$1.19	\$1.16	\$1.17	\$1.13	\$1.19	\$1.16
14	4.75	9.43	4.07	\$1.19	\$1.13	\$1.15	\$1.14	\$1.19	\$1.14
15	4.93	9.42	4.01	\$1.19	\$1.14	\$1.15	\$1.14	\$1.19	\$1.15
16	5.17	9.40	3.88	\$1.19	\$1.16	\$1.17	\$1.13	\$1.19	\$1.16
17	5.14	9.50	3.97	\$1.19	\$1.14	\$1.16	\$1.14	\$1.19	\$1.15
18	5.12	9.57	4.03	\$1.19	\$1.14	\$1.16	\$1.14	\$1.19	\$1.14
19	5.18	9.47	4.08	\$1.19	\$1.13	\$1.15	\$1.15	\$1.19	\$1.14
20	5.29	9.69	4.29	\$1.19	\$1.10	\$1.13	\$1.17	\$1.19	\$1.12
21	5.44	9.63	4.21	\$1.19	\$1.11	\$1.14	\$1.17	\$1.19	\$1.12
Min.				\$1.19	\$1.10	\$1.13	\$1.13	\$1.19	\$1.12
Max.				\$1.19	\$1.33	\$1.31	\$1.49	\$1.23	\$1.33
Ave.				\$1.19	\$1.20	\$1.20	\$1.20	\$1.20	\$1.21

cheese. Fat and protein proportions are automatically adjusted by the process of making cheese. Farmers are encouraged to produce milk with high cheese yielding capacity because they are paid more for such milk.

Milk procurement should be more than a contest between neighboring cheese plants to see who can buy the most milk. Buying more milk is not very helpful if you are paying more for the milk than it is worth as cheese. Some of the payment systems in use or being considered are not what they seem to be on the surface. A careful comparison should be made between all available systems before any one is adopted.

#### REFERENCES

1. Ernststrom, C.A.. 1980. A workable milk pricing system based on cheese yield. Utah State University 4th Biennial Cheese Industry Conference, Logan, Utah.
2. Milk Industry Foundataion. 1982. 1982 Milk Facts. Washington, D.C.
3. Van Slyke, L.L. and W.V. Price. 1952. Cheese. Orange Judd Publishing Co., New York, N.Y.

### Principle:

All living cells contain ATP as an energy-storing substrate. Because of its importance in all metabolic pathways, cells maintain a relatively constant level of ATP. This, and the fact that dead cells rapidly lose their ATP through autolysis, allows ATP assays to be used as a rapid measurement of viable cells. The assay of ATP using the principles of firefly bioluminescence is extremely sensitive. In certain applications, a level of  $10^3$  CFU/ml can be detected.

Unlike earlier methods based on ATP assays, the LUMAC/3M MILK BACTERIA KIT procedure applies new, purified reagents, more sensitive instrumentation as well as improved sample processing to eliminate nonmicrobial ATP and to release the microbial ATP.

The test procedure consists of selectively releasing the ATP from nonmicrobial cells using a patented reagent, NRS. This reagent makes the membrane of mammalian cells permeable for small molecules like ATP, but leaves microbial cells unaffected. The ATP that diffuses out of mammalian cells during a 45 minute incubation is hydrolyzed by a calcium-activated ATPase enzyme (SOMASE reagent). After the incubation, a releasing agent for bacterial ATP (L-NRB reagent) is used to make both the cell wall and the membrane of microbial cells permeable for small molecules. Following the addition of NRB reagent and the subsequent release of microbial ATP, the level of ATP is assayed by adding purified firefly luciferin-luciferase reagent (LUMIT-PM) and then measuring the light emitted with a single photon counter (M2010 BIO-COUNTER). The measurement is in RLU's.

### THE MODEL 2010A BIO-COUNTER:

The 2010A Biocounter is a microprocessor-controlled photon counter. Its ease and flexibility of operation make this instrument ideal for luminescent measurements in clinical, environmental, agricultural, food, cosmetic, and research applications. The M2010A offers the following features:

- State-of-the-art microprocessor control.
- Three dispensers which allow automatic reagent addition or manual addition for custom applications.
- A WASH and PRIME mode for ease of instrument preparation.
- Added flexibility through the use of the following accessories:
  - RS232-compatible interface for computer control.
  - Thermal printer which automatically records test results.
  - Analog cable for oscilloscope or strip chart recorder interfacing.

Technical Reference: Milk Science International, R. Bossuyt, Milchwissenschaft 36 (5), 1981, pp. 257-260

Discussion and Conference NOTES:

## PETRIFILM

### Petrifilm SM Plates:

#### Description:

The Petrifilm® SM Plates contain Standard Method (SM) nutrients and a cold water soluble gelling agent. The bottom film is coated with SM nutrients and the gelling agent; the top film is coated with the gelling agent and a tetrazolium indicator dye. This indicator stains the colonies red and facilitates counting. The grid on the bottom film also aids in counting.

Technical Reference: Journal of Food Protection, article by R. Ginn (accepted for publication).

NOTES from Conference and Discussions:

## Petrifilm VRB Plates:

### Description:

The Petrifilm VRB Plates contain Violet Red Bile (VRB) nutrients and a cold water soluble gelling agent. The bottom film is coated with VRB nutrients within a circular well; the top film is coated with the gelling agent and a tetrazolium indicator dye. This indicator stains the colonies red and facilitates counting. The grid on the bottom film also aids in counting. When coliforms ferment lactose, gas is produced. The films trap the gas around the coliform colonies and thus differentiates them from colonies of other gram negative organisms.

Technical Reference: Journal of Food Protection: Vol. 47, #7 July 1984,  
pp. 520-525. Article by Frank Busta

NOTES from Conference and Discussions.



March 11, 1988

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1984 ENTIRE ARTICLE  
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# NEW APPLICATIONS FOR ELECTRICAL IMPEDANCE MEASUREMENTS: STARTER ACTIVITY, ABNORMAL MILK DETECTION, ANTIBIOTIC DETECTION, COLIFORM COUNTS

G.H. Richardson  
Sixth Biennial Cheese Industry Conference  
Utah State University, Logan, UT, 84322  
30 August 1984

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## INTRODUCTION

Perhaps the most exciting breakthrough in automated microbiology in the last century is associated with impedance instrumentation. It is a difficult concept for traditional microbiologists to accept because it does not involve counting colonies on an agar surface. We are used to waiting two to three days for billions of bacterial cells to develop so we can see them on an agar surface but we cannot accept waiting a few hours for biochemical changes to occur. These changes cause different electrical properties in a medium that can be measured by sensitive instrumentation (4). Impedance instruments, offered by Bactomatic Inc. in the USA (Bactomatic Inc., PO Box 3103, Princeton, NJ 08540) and Malthus Ltd. in the UK, are particularly applicable to the dairy industry since they can test for many of the routine things that we now do in the dairy laboratory. They are currently under intense study in the USA, Europe, and New Zealand. I think this instrumentation is now where infrared instruments were about ten years ago and I have said that five years from now they could well be the standard method for the Standard Plate Count for instance.

Canadian microbiologist Anthony Sharpe has said of this instrumentation (5), "...that most microbiologists must now consider abandoning the old and trusted tool (plating methods) in favor of more efficient modern instrumentation. And of the available techniques, electrical impedance must, through its rapidity, versatility, compatibility with automation and computerized control, and pertinence to the total metabolic activity of the organisms - be considered a most desirable approach." He also indicated that, "...microbiologists are obsessed with the counting of clusters of bacteria which can grow on agar". He pointed out that, "...the ability of food to cause illness, or otherwise become unwholesome, depends on five factors; (i) number of organisms; (ii) their

rate of multiplication; (iii) the contribution of each microbial cell to the unwholesomeness of the food; (iv) inhibition or stimulation of (ii) and (iii) by other organisms; and (v) the consumer response thresholds to the levels of the various parameters. Counting microorganisms provides information on only the first item of the above list. Methods measuring levels of some physical, chemical, biochemical characteristics of the measured organism can provide information on factors (i) to (iv). Therefore, it is probable that these new methods, such as impedance, are a better direct measurement of the quality of foods than the standard plate count method."

You can see why I am excited about this new instrumentation. We are cooperating with Bactomatic Inc. on developing new uses for this technology in the cheese industry. A unit is on display today in this building.

#### WHAT IS IMPEDANCE?

A kink in the garden hose represents a resistance to the flow of water (Figure 1). Less water is thus conducted through the hose. Likewise, resistance in an electrical circuit inhibits conducting electricity. Resistance and conductance are used to describe direct current characteristics. Impedance and admittance are used to describe the characteristics associated with alternating current systems. For simplicity and because it is most frequently plotted in dairy research, I will use conductance for both direct and alternating systems. Most dairy applications will involve the use of conductance measurements since ionic substances are produced by the bacteria of interest. However, if alcohols are produced, for example, then capacitance measurements might be preferred.

Now how can conductance or capacitance tell us about microbial activity? If we place two electrodes into a medium and induce an electrical signal there will be impedance against the flow of current depending upon the number of ions or compounds between the electrode. If we add more ions, the impedance is reduced and the conductivity of the medium increases. Nonionic substances in milk including lactose, fat, and, proteins become converted to acids by bacterial activity (Figure 2). Acids are more ionic. Conductance increases as acids increase.

#### CONDUCTIVITY INSTRUMENTATION

The Bactomatic 123 is composed of an incubator, computer and print-out systems. Eight modules with 16 wells each can be plugged into the incubator making it possible to run 128 samples simultaneously. Each

well has two electrodes imbedded. Modules are sterilized and ready for addition of sample or medium. If large samples are required, then bottles are available with special electrodes.

## CURRENT APPLICATIONS FOR THE DAIRY INDUSTRY

### INCOMING MILK, STANDARD PLATE COUNTS

Conductance measurements can be made in hours rather than the days required for the standard plate count, and with more precision (3,6,8). In fact, estimates can be made of total, mesophylic, or psychrotrophic bacteria in milk (6). For the standard plate count estimate, rich agar medium is allowed to solidify in each well. Raw milk is added (Figure 3) and then the well is placed in the incubator and the computer monitors the conductivity every 6 minutes. As metabolites are produced by microorganisms, they diffuse into the agar but little detectable change occurs in conductance until about  $10^7$  colony forming units per milliliter of milk are present. When this occurs, the rate of conductivity change is significantly different than before and the detection time is calculated by the computer. This value can be used to calculate the initial numbers of bacteria present in the milk as received (Figure 4). If we had a standard of  $10^5$  cfu/mL the instrument would indicate the sample below standard with a red zone in about 4 hours. If it was higher the results would be a red signal earlier. A caution signal would indicate a doubtful area and green would indicate the sample to be well below our standard. Sample readout is continuous, automated, and available in much less time. The method correlates extremely well with the standard plate count, over .95! This method has received the approval of the Technical Committee preparing the Standard Methods for the Examination of Dairy Products (SMEDP-15) and will be clasified A2 in the 15th edition now in press (10).

### KEEPING QUALITY

Plate counts are very poor tools in helping the dairy industry predict keeping quality of pasteurized dairy products. They must be improved by using preliminary incubations. Some of the best, such as the Moseley test, require seven to nine days before the results are available. Conductance methods have shown promise in evaluating post-pasteurization contamination (2). Bishop *et al.* at Louisiana State University (1) found conductance methodology to be best for predicting the shelf life of pasteurized whole milk. The correlation between what actually happened

and the Moseley test was -.84 but for the instrumental method it was .87 or .88 depending upon the incubation temperature used and the results were available in from 20 to 31 hours! This methodology is also approved and will be in SMEDP-15. Dr. White recently confirmed that studies on cottage cheese have established that conductance measurements provide the best estimates of keeping quality.

The instrumentation is also being used to determine laboratory pasteurization count at one dairy. Others have applied it for measuring the shelf life of ultrapasteurized products.

### COLIFORMS

Presumptive coliforms in dairy products can be easily estimated by addition of products to a special medium, incubating and running the conductance measurements (7). The method produced correlation coefficients of from .91 to .95 when compared to the violet red bile agar plateing method. These values were obtained on raw milk, pasteurized milk, heavy cream, and ice cream mix. The test for coliforms in raw milk is approved and will be in SMEDP-15.

### BACTERIOPHAGE

Researchers in Belgium (11) have used conductance measurements to note when bacteriophage (phage) activity is high enough to retard cheese manufacture. Sterile reconstituted nonfat dry milk, lactic culture, and the milk to be used for cheese which could contain the phage, are added to a well and the results compared to samples in wells that are free from the added cheese milk. Within two hours, differences in acid production rates were detected in the conductivity readings. This suggests that other inhibitors might also be found.

### YEAST IN YOGURT

Zindulis (12) recently reported the value of this instrumentation in estimating yeast contamination of yogurt. Antibiotics were added to growth medium to inhibit bacteria. Capacitance measurements were made and a yeast contamination of  $10^3$  could be detected in 20 hours. A correlation of -.92 was found between the detection times and yeast plate counts of naturally spoiled yogurts.

## POTENTIAL APPLICATIONS FOR THE DAIRY INDUSTRY

### ABNORMAL MILK

When the milk secretion tissues are normal, lactose is manufactured at the membranes. When these tissues become mastitic or damaged, the lactose synthesis is reduced. Since there must be a constant osmotic pressure in milk, salt ions enter the milk to compensate for the reduced amount of lactose. Salt ions will conduct more electricity than lactose so the conductivity increases.

Okigbo *et al.* (9) recently reported the wide-range portable conductivity meter used for cowside detection of abnormal milk. The Mas-D-Tec™ (Figure 5 is a handout of the portable conductivity meter)(Wescor Inc. 459 S. Main St. Logan, UT 84321) is now being sold by the hundreds for producers to detect abnormality in samples from individual quarters. This instrument must use direct current conductivity because of its size and cost. Dr. Spahr and coworkers at the University of Illinois is also investigating the measurement of conductivity in milking machine claws.

Recently, Khayat (Unpublished) found that the conductivity baseline of the Bactomatic readings changed with the degree of abnormality of the milk sample. The variation between normal and abnormal milk was greater than that between wells of the modules. For example, the normal well-to-well variation was on the order of 2 % while the differences between normal and abnormal samples ran from 50 to 80%. We are now looking to see if both abnormal milk and bacterial numbers can be detected from the same sample. This would be possible if we could get a baseline that was indicative of abnormality and then a detection time that indicated when the bacteria had reached  $10^7$  cfu/mL.

#### ACTIVITY TESTS

I described how phage testing had been evaluated in Belgium (11). That test is really an activity test in which inhibitors are present. Uju Okigbo (Unpublished) is developing an activity test that would apply for use in the cheese industry. Lactic culture is added to milk and the shape of the conductivity curve is measured over the first hour. She has found very high correlations (>.9) to changes in pH when compared to conventional five-hour activity tests. One to five percent culture is mixed with milk and transferred into a well. After one hour at 30°C, the change in conductance is used to estimate inoculum levels or a slow up of culture activity.

We shall evaluate the instrument using thermophilic and protease negative lactic cultures. Perhaps the slope of the conductance readings can be used to characterize these cultures.

### ANTIBIOTIC TESTS

Bacterial inhibitors have been placed in milk and the milk placed on agar containing spores of *Bacillus stearothermophilus* var *Calidolactis*. This is the basis of current antibiotics tests such as the Delvotest™ and the DIFCO™ disk assay. Using conductance instruments, the inhibitors reduced conductance changes and we had an endpoint that was not dependent upon reading subtle color changes or differences in zone diameters. The more objective endpoint could be reached in less than or in greater than 2.5 hours so the test could be more sensitive. We are continuing this work.

Another approach is to use the lactic cultures in the cheese plant as the test organisms. We could quantitate the antibiotics by comparison with known standards. Wells would be filled with raw milk with one to five percent added culture. Changes in conductance would be monitored and compared with control wells containing sterile inhibitor-free milk with culture. This may provide a more objective method than now available to help fine-tune inoculum levels in cheese vats, even when antibiotics are not present but milk inhibition exists.

### CHEESE CURD MEASUREMENTS

Up to now the development of acid in cheese curd has been limited to using titratable acidity or pH of the whey. Usually the pH of curd is taken of cheese curd after pressing. Conductivity measurements have the potential for application during the cheese make in the cheddaring stage where we are most concerned about rate of acid production. Such measurements might also be relevant in salting and salt distributions. Perhaps we can even get handles on cheese aging!

### OTHER POSSIBILITIES

I have speculated on many potentials, some of which may not prove practical. However, the measurement of biochemical activity should be possible with all microorganisms. Thus we can guess that we should find future applications yet unmentioned. For example, suggestions for some microbial standards in cheese have been abandoned because of insignificance of the data. Yet we still have cheese recalls because of salmonella and coliforms in cheese. Thus we should see what conductance technology would do for coliforms, staphylococci, and salmonella in cheese. Perhaps it would provide a quality assurance tool that would reduce recalls



and allow standards to be developed that have been previously abandoned.

#### COUNTING COLONIES VS. MEASURING METABOLITES

All of the methods discussed work because we now can measure development of breakdown products in milk. And I can promise you it is much more fun than counting colonies on smelly agar!

#### APPROVAL OF METHODOLOGY

Standard plate counts, shelf life tests, and coliform tests can now be run on milk using SMEDP-15-, or American Public Health Assoc., approved methodology. However, an interpretation of the Pasteurized Milk Ordinance has literally shut down the sales of conductance instruments in the dairy industry. The only ones willing to benefit from this breakthrough are those who are not involved in regulatory testing. One large Co-op, brave enough to use it anyway, indicated they would go back to the old standard plate count only if the regulatory agency would pay them the difference in cost for doing it the antiquated way. Fortunately, they have been allowed to continue the use of the instrument and save money and time. We are currently attempting to defend the APHA as the agency deciding upon microbiological standard methods. We are simply asking that the PMO be clarified to assure that the APHA, the AOAC, and the FDA are allowed to approve new methodology. This is the intent of the PMO but it is not currently interpreted as such. If this is not changed, there is no need for either the APHA or AOAC!

#### CONCLUSIONS

We view the potential for conductance instrumentation to be extensive. Milk can be evaluated at the cowside and while passing through milking machines. The cheese industry should be able to evaluate incoming milk microbial quality and abnormality. Cheese industry laboratories can additionally use the technology to detect inhibitors and evaluate culture activity. The instrumentation should also prove useful in evaluating coliforms, staphylococci, and salmonella in cheese and thereby initiate reexamination of standards for these parameters that have been difficult to put handles on in the past. We may also see these measurements being taken in the curd where we have not been able to make practical estimates of acid changes in the past. Automated and more economical testing would encourage more testing to assure finest quality. I am excited about conductance technology for it represents the best

breakthrough in microbial technology to date. Please join me in helping it become the standard of the future.

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Figure 1

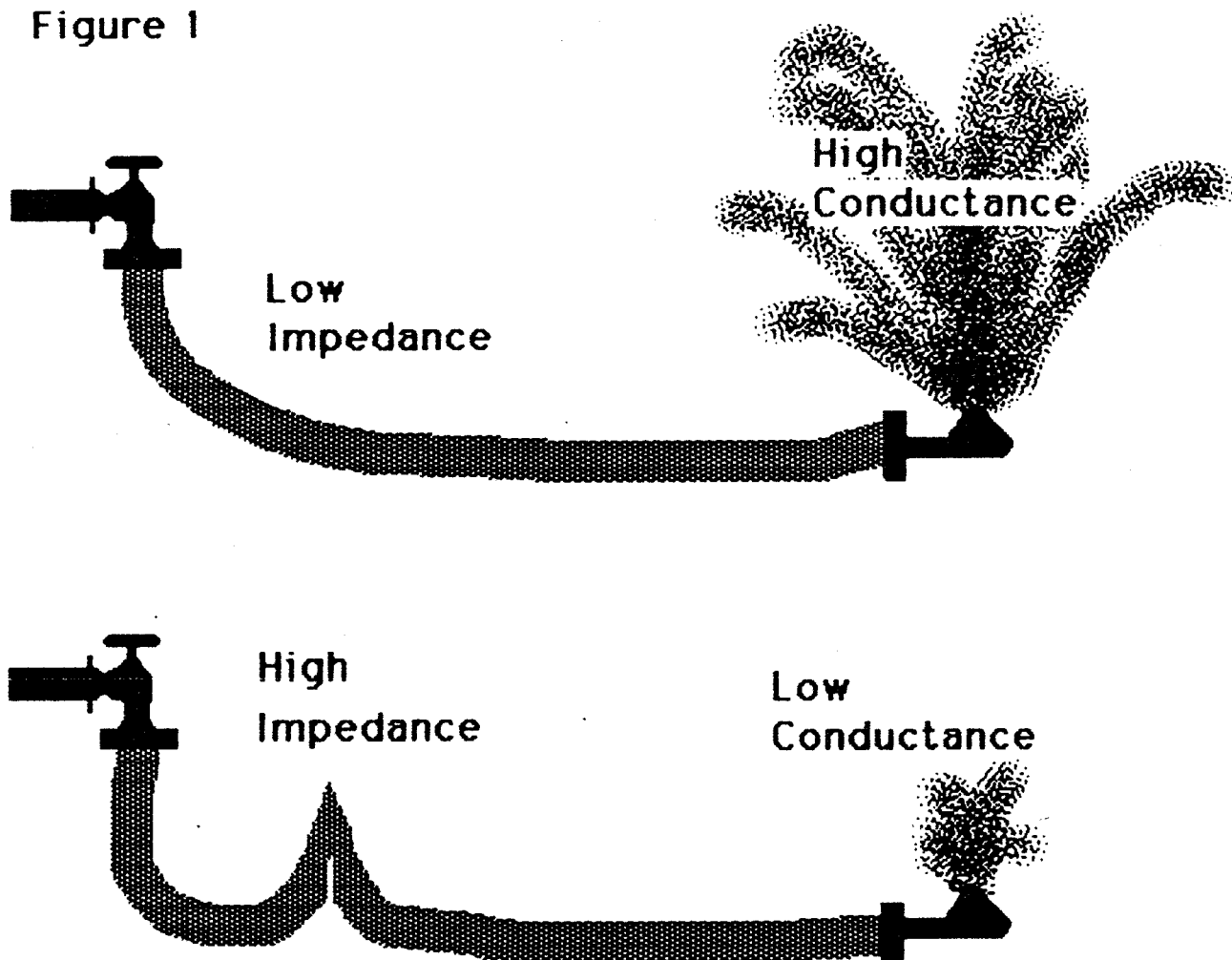
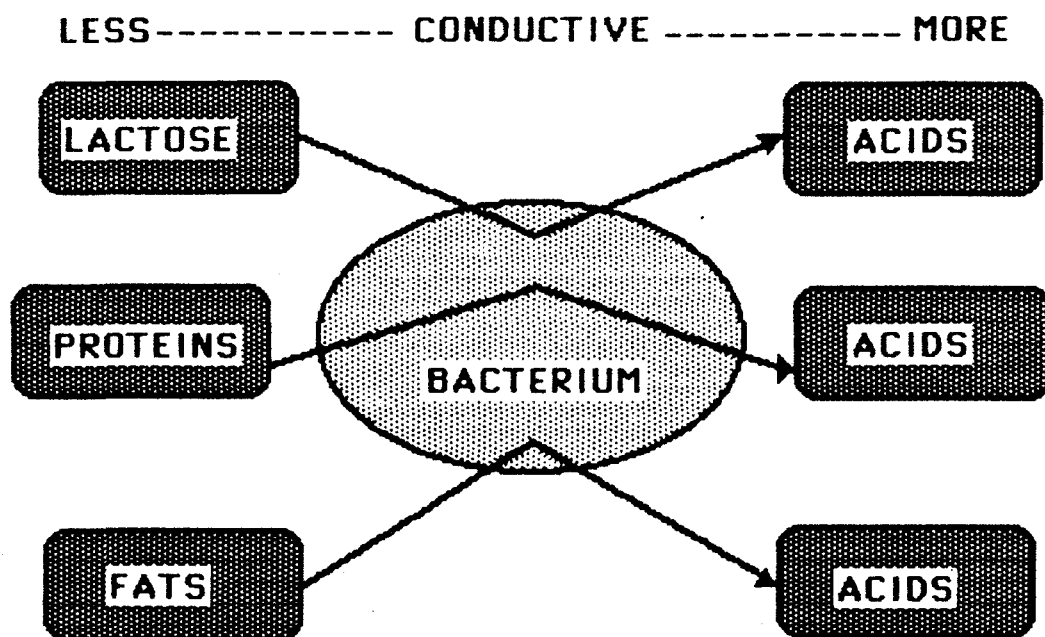


Figure 2



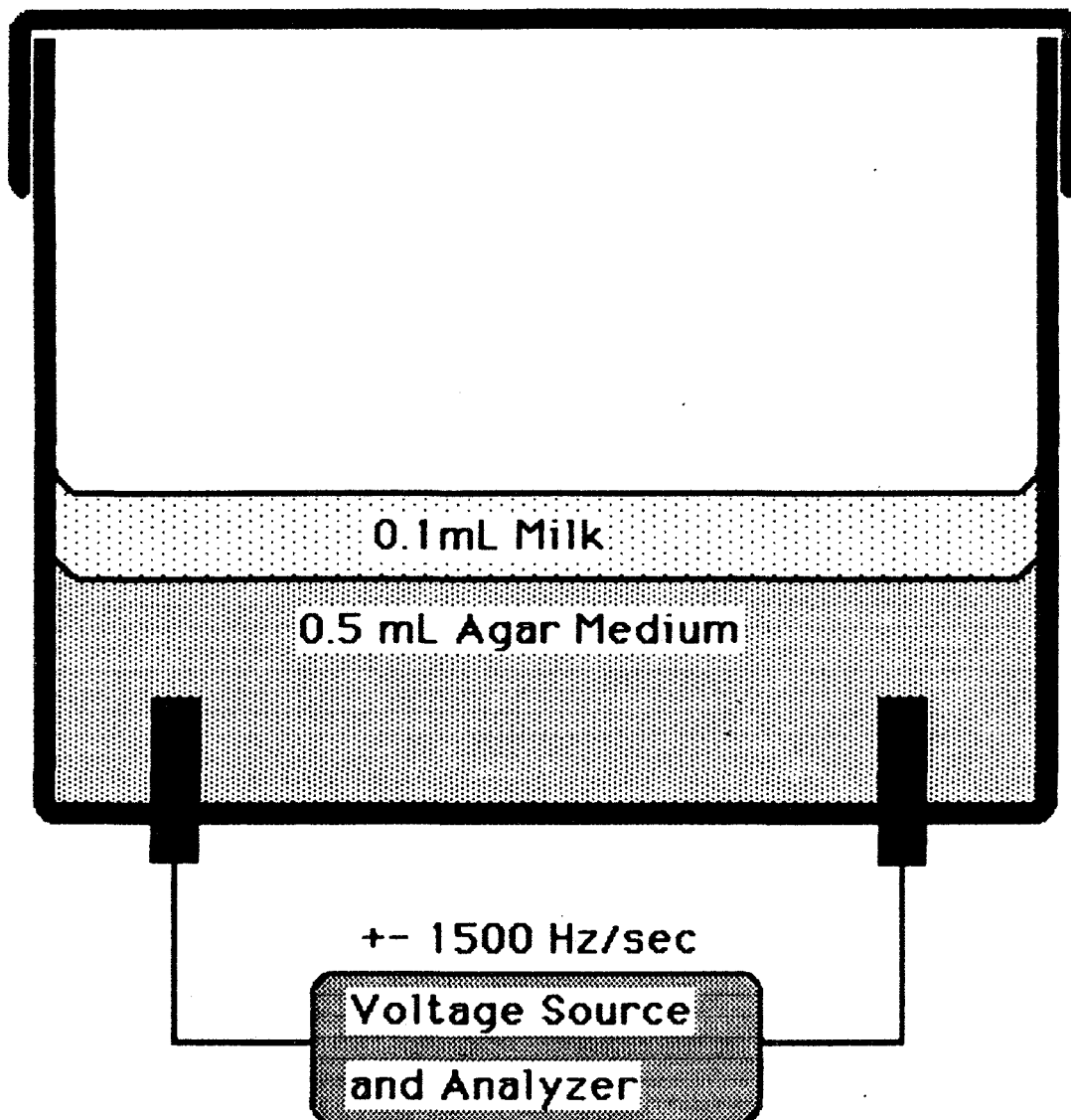
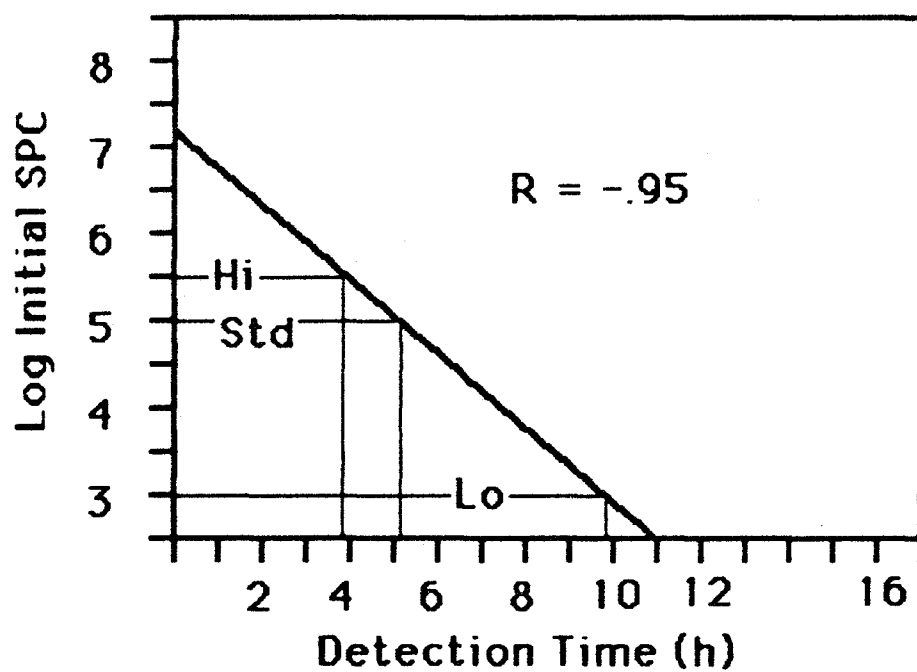


Figure 3

Figure 4







**MAS-D-TEC™ by Wescor offers a new development in electronic technology: Early Mastitis Detection. It meets the requirements of a modern dairy operation and provides the manager with a simple, convenient and instantaneous means of detecting subclinical mastitis. It eliminates the guesswork and time-consuming fuss associated with old-fashioned chemical tests for mastitis detection.**

MAS-D-TEC measures electrical conductivity in a small sample of milk. Research has shown that conductivity increases markedly with the onset of mastitis infection. MAS-D-TEC uses sophisticated technology to detect increases in conductivity long before other clinical symptoms and signs are evident.

With an average dairy of 120-150 cows losing up to \$37,500 to mastitis every year, it is no wonder there has been so much talk among dairymen about mastitis. It is estimated that at least 50% of all cows are infected with mastitis. Most dairy farmers deal with the obvious clinical cases and usually overlook the less obvious, but far more costly, subclinical mastitis. Those dairymen who are best informed as to herd health will be those who, through the application of good management factors, will ultimately have the "cleanest" herd. In the past, detecting subclinical mastitis was difficult. MAS-D-TEC makes it easy to detect and provides critical feedback.

Laboratory analysis of somatic cell count in milk can indicate the presence of mastitis infection. However, since such analyses are performed away from the dairy and are not specific to the individual quarter, the results do not provide a means for mastitis detection as effective as MAS-D-TEC. Frequent herd monitoring with MAS-D-TEC will enable prompt action, providing effective, economical control of mastitis in your dairy herd.

**MAS-D-TEC**



#### **SIMPLE TO USE**

MAS-D-TEC is a hand-held electronic instrument having a funnel-like opening at its top. The sample of milk is squirted directly from the teat into this opening. The sample volume required is only 2 milliliters (one or two squirts). Anyone can obtain reliable results with MAS-D-TEC as there is no special training necessary for its use.

#### **ECONOMICAL**

With estimates of yearly losses due to mastitis ranging up to \$250 per cow, MAS-D-TEC (for only \$295) will quickly pay for itself, even with relatively small herds.

#### **INSTANTANEOUS COWSIDE RESULTS**

After the milk sample has been introduced into MAS-D-TEC, the operator then presses a button on the front of the instrument. The result appears instantaneously and the entire procedure can be accomplished in less than five seconds per quarter.

#### **DURABLE**

MAS-D-TEC's electronic circuitry is completely enclosed in a strong, waterproof case for long, dependable service in the milking-parlor environment. MAS-D-TEC is warranted for one full year.

#### **SELF-PURGING**

MAS-D-TEC is designed so that the previous milk sample is purged from the system by the introduction of a new milk sample. Thus, there is no need for cleaning the instrument between quarters or between cows. A clean water rinse after each milking of the herd is all that is required.

#### **PORTABLE**

MAS-D-TEC is designed for hand-held operation and is powered by a readily available standard 9 volt battery. More than 1,000 cows can be tested on a single battery, and the instrument provides a low-battery warning.

#### **ACCURATE READINGS**

A reading ranging from 0 to 9 will be indicated by the instrument. Readings of 0 indicate extremely low electrolyte content in the milk and a healthy quarter. Readings between 0 and 4 are acceptable. Any reading of 5 or higher should be interpreted as a positive indication of subclinical mastitis in that particular quarter.

For ordering information contact Wescor, Inc, 459 So. Main Street, Logan, Utah 84321, or phone toll free **800-453-2725 (inside Utah, call 752-6011).**

**WESCOR**

## What's Happening with Antibiotic Testing

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Presence of antibiotic residues in milk as it leaves the farm is a major problem for the dairy industry. Antibiotics cause retardation or failure of starter culture organisms. Allergic reactions to antibiotics and loss of sensitivity of the general population to antibiotics are serious concerns. The public's fear of residues, additives and other "unnatural things" in food may be as disturbing as any of the real objections. Regulatory pressure which will force us to solve the antibiotic problem is on the horizon. We will be much better off if we take care of it ourselves before this happens.

Milk containing antibiotics is mixed with other milk before it leaves the farm. The farmer is blamed when accidents occur and the penalties are often severe. Detecting antibiotics in milk from a silo or even a tank truck tells us we are already in a predicament. We need to find unacceptable levels of antibiotics in milk from individual cows on the farm and prevent such milk from ever being sold. The antibiotic problem will not be solved until we put our emphasis at the place where the adulteration occurs.

A list of requirements for a satisfactory on farm antibiotic test was compiled several years ago. The criteria were:

1. The test should be sensitive to .01-.05 penicillin units per ml of milk.
2. The required time for a single test should not exceed five minutes.
3. Untrained personnel should be able to perform the test.
4. The cost per test should not exceed \$ .25.
5. The test should be adaptable to antibiotics other than penicillin.

The price may have risen slightly, but this list still contains the critical points for a successful test. Most emphasis in testing has been directed toward penicillin, mainly because penicillin is used for mastitis treatment more frequently than any other antibiotic. The necessity for the fifth point on this list will increase as use of other antibiotics increases.

Many companies have become interested in the dairy industry's antibiotic problem. Tests are now commercially available which meet the requirements listed here to various degrees. We are very happy to have representatives from several companies available to discuss their products and answer questions.



# **Getting the most "clot" out of your milk**

**G.H. Richardson**

**Sixth Biennial Cheese Industry Conference**

**Utah State University, Logan, UT, 84322**

**28 August 1984**

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## **INTRODUCTION**

**Milk coagulation is a complex process. Serious losses can occur in dairy products manufacture, especially cheese, if poor clotting occurs. Failure of the lactic cultures to coagulate cottage cheese milk, because of bacteriophage activity, has caused milk to be discarded. Significant losses in yield of Cheddar cheese have been associated with cutting coagulum when it is too soft (2). Coagulum quality can be improved by adjustment of milk acidity, enzyme coagulant concentration, calcium chloride addition, and temperature (6). Milk storage conditions and bacterial content also affect milk clotting quality (1). Dairy researchers have not looked much at the clotting qualities of milk from individual cows. The development of the Formagraph (4) made possible the examination of 10 mL quantities of milk so that quarter samples could even be examined for clotting characteristics. Today, I will discuss the variability in coagulation associated with milk from individual cows, how we can measure coagulation, and how we can improve the coagulation properties of pooled milk. We desire to optimize this to assure the best product quality, yield, and moisture control.**

## **MEASUREMENT OF COAGULATION**

### **LABORATORY**

**Dr. Reuben Hill, a Utah State University Chemist, developed the Hill Curd Tension test in the 1920's. Pepsin was added to milk and mixed. A knife was placed in the bottom of the beaker and the milk was allowed to clot. After 30 minutes at a set temperature curd tension was measured by determining the force required to pull the knife up through the curd. Subsequently, curd tension was determined by driving a knife down into curd. Several approaches have been developed for continuous curd tension measurements. One of the best is embodied in the Formagraph built by Foss Electric, Denmark (4). We have the only one of these still in the USA and have conducted considerable work with it in our laboratories. It consists of a service**



and a test module. Milk substrate is tempered in 10 mL quantities, inoculated and mixed with enzyme coagulant, transferred to the test module and observed for coagulation. The forces which develop against a vertical loop, as the milk tray is moved from side to side, create drag upon the loop. Mirrors on the loop mechanism are used to reflect strobe light flashes every six seconds onto light sensitive paper. The resultant pattern changes from a straight line to a wishbone-like curve as milk coagulum forms. Such a curve provides better estimates of cheese cutting times.

### **CHEESE PLANT**

In cheese plants the traditional methods of curd firmness measurements are very subjective and vary from one cheesemaker to another. Usually a thermometer or finger is inserted into the curd and raised to note the curd quality. Or the flake time multiplied by a factor to get cutting time is used. We learned that hot matches have been dunked to estimate curd quality. We have observed a three fold variation of curd firmness in Swiss and four fold variation in Cheddar cheese as we have objectively measured what is being done in three local cheese plants. Several instruments have been developed around the world recently with the most applicable being those developed in Australia by Vanderheiden (3) and in Switzerland as reported by Schar and Fluckiger (8). You may recall that, at our last Cheese Industry Conference, both Dr. Robert Sellers and Dr. Norman Olson suggested the need for an improved instrument to produce more objective cutting-time in vats. With the help of graduate student, Leslie Okigbo and USU civil engineer, Derle Thorpe, we had an instrument in a matter of a few months that appeared rugged and effective in providing such information (7). In June of last year an agreement was signed between the USU Foundation and the CEM Corporation of Indian Trail, North Carolina, to develop and market the instrument we have tentatively called the "VAT TIMER" for use in pilot and large cheese plants. We hoped one could be shown here. The first commercial model is designed to be moved readily from vat to vat and provide an alarm when the preset curd tension for cutting is reached.

We are examining the value of the shape of the curve drawn by such instrumentation. For example, Dr. Okigbo demonstrated that coagulation curve shape changes with variations in casein composition (6)(Table 1).



**Table 1. Percentages of casein fractions in good and poor coagulating milk samples. Electrophoretic analyses.**

Milk	$\delta_s$	$\beta$	k	para k+g	? lamda?	
GCM	56.3	18.3	18.8	4.8	4.8	
PCM(W)	42.2	9.7	13.2	33.9	1.0	
PCM(N)	29.7	8.3	14.0	28.4	6.6	13.5

W=Weak coagulum      N= No coagulum in 30 min.

When the major caseins decreased ( $\delta_s$  and  $\beta$ ) and the minor ones increased (gamma and lamda and ?) as the cow produced them or as proteolysis occurred, the curve narrowed and eventually became a straight line. Thus no coagulation was indicated. If we could get some measure of the quality of the casein or the degree of proteolysis in the coagulating milk, by calculating certain parameters of the curve, it would be of more benefit to the industry. If we could estimate some factor such as the maximum curd strength obtainable from the data developed, this could help improve quality control of milk handling and milk payment incentives. Even if these data cannot be practically applied, there appears to be other economic incentives to the use of this instrumentation. Some excellent yield studies were recently completed at the CSIRO in Highbett, Australia. Southerland and Mayes (9) used the Vanderhelden instrument to objectively determine cutting time. Using 600 Kg vats, they ran several hundred trials and concluded that there was no difference in yield over a cutting strength range that varied over about 90%! They concluded that the \$16,000 instrument would only pay for itself when milk failed to clot but it was not necessary for routine plant operations. We think this to be an advantage, however, since considerable savings could be generated in enzyme coagulant costs that would soon pay for such an instrument. One could simply adjust the coagulant to the objectively-derived minimum cutting strength, consistent with maximum yield. Additionally, better control over product moisture, texture, and make schedule would result. Currently we are evaluating the modifications required to adapt the instrument for use in small volumes of milk in laboratories. We have obtained a very sensitive detector that should allow us to develop a laboratory model of this instrument.

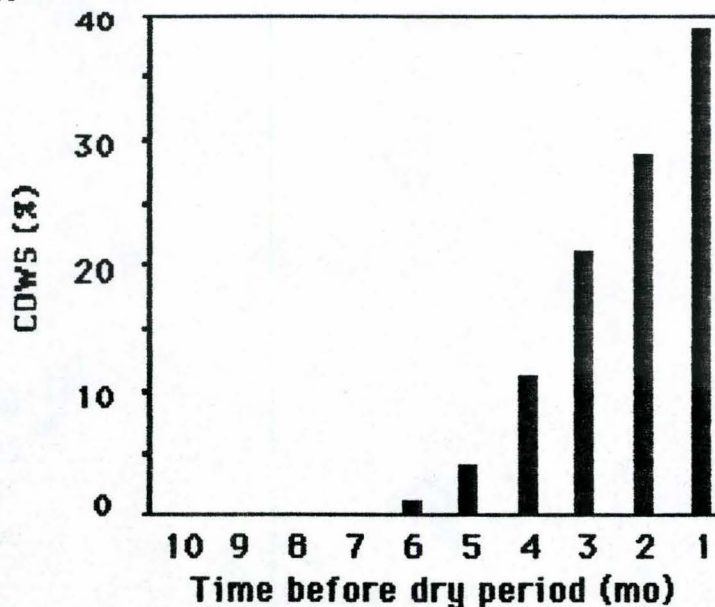


Seven prototype instruments are being assembled for evaluation in the field. The model will be finalized depending upon the field experiences with these units. There have been numerous inquiries and most cheesemakers have demonstrated a desire to use such an instrument.

#### THE PROBLEM

When Leslie Okigbo started measuring milk coagulation on the Formograph for his Masters Degree project (5), he found more variation in milk curd strength than anticipated among animals under the same herd management. In the USU Holstein herd, 38% of all animals, one month prior to their dry period, produced milk that failed to coagulate in 30 minutes (Figure 1).

Figure 1.



Fewer animals produced such milk as the distance prior to the dry period was increased. It became evident that normal milk from some animals should be used for applications where coagulation was not involved, that animals might be genetically selected for cheese manufacture, that they should be dried up earlier, or they should be shunted to make Big Macs instead of cheese!

#### SOLVING THE PROBLEM

We first used the method now routinely used to solve this problem; blending poor coagulating milk with good (6). We would thus expect a weaker clot but that most of the protein would be entrapped and normal cheese would result. This was not true in all cases when

blends were prepared. Table 2 shows the 30 minute curd strength when good coagulating milk (GCM) was mixed 50/50 with poor coagulating milk (PCM). The coagulum was poorer than expected in some cases, equal to expected in others and superior to expected in still other cases. The PCM formed a fair clot in the latter examples so the blend results were better than when the PCM did not clot at all. The results appeared to be dependent upon the characteristics of milk from particular animals used in the blend. When PCM and GCM samples were pooled they did not coagulate in 30 minutes. Pooled GCM with 45mm strength was blended with pooled PCM with 0 strength and the result was 0 and the pH was significantly higher.

**Table 2. Curd strength (mm) in blends of GCM and PCM 30 minutes after rennet addition.**

<b>GCM</b>	<b>PCM</b>	<b>50/50 Blend Expected</b>	<b>Found</b>
<b>52</b>	<b>0</b>	<b>26</b>	<b>9</b>
<b>51</b>	<b>0</b>	<b>25.5</b>	<b>7</b>
<b>53</b>	<b>0</b>	<b>26.5</b>	<b>2</b>
<b>49</b>	<b>25</b>	<b>39</b>	<b>39</b>
<b>45</b>	<b>35</b>	<b>40</b>	<b>40</b>
<b>40</b>	<b>28</b>	<b>34</b>	<b>35</b>
<b>45</b>	<b>3</b>	<b>21</b>	<b>39</b>
<b>45</b>	<b>19</b>	<b>32</b>	<b>38</b>
<b>42</b>	<b>17</b>	<b>29.5</b>	<b>35</b>

We investigated the various parameters that might allow us to improve the clotting process in the cheese plant. When used alone, addition of calcium chloride, adjustment of pH, or modification of rennet concentrations were found to be of little value. However, when the milk pH was dropped to 6.4 by the addition of lactic acid, rennet addition was reduced to 50% of normal, and 0.02% calcium chloride was added, the rate of increase of curd firmness was improved substantially. In one example the curd strength of PCM went from 16.9 to 19.5mm upon pH adjustment, to 21mm when  $\text{CaCl}_2$  was added, to 31.6mm when rennet was reduced. It was most interesting that increasing rennet did not increase curd strength as we have routinely thought. When curd was made from such adjusted milk in the laboratory, the yields were only 65% of GCM, the moisture of the curd was 60% compared to 41% for GCM, and the curd quality was very poor quality.

#### **EFFECT OF MILK STORAGE**

As previously mentioned, poor coagulating milk has significantly different ratios of caseins than GCM (Table 1). The poor quality caseins increase during milk storage (1). This adversely affects cheese yield. In order to minimize losses of curd forming properties during the time milk is collected and coagulated, it is suggested that every effort be made to minimize protease (plasmin) and psychrotrophic bacterial activity in milk. This can be done by storing milk at lowest possible temperatures for the shortest times before coagulation. In one study by Dr. Okigbo (6), mixtures of GCM and PCM dropped from 40.5 to 30.4 to 28.6mm curd strength during 4C storage at 0, 48 and 72 hours, respectively. Samples of PCM dropped from 16.5 to 5.25mm, for a 68% loss in curd strength during storage at -1C for 30 days. Samples of GCM during the same conditions lost 8% as curd strength dropped from 55.5 to 51.25mm.

#### **CONCLUSIONS**

In order to maximize the clotting of milk for cheese manufacture we should test every animal, especially during late lactation, to see if she produces noncoagulating milk. Such milk should be shunted from the manufacture of cheese. Animals which display this trait persistently might have genetic properties that should be considered in selection and breeding. Lactation periods should be



shortened on animals producing high levels of plasmin or protease activity. When milk is pooled it should be stored cold and processed with a minimum of delay. There are significant modifications that can be made in the Cheddar cheese process that will assure better coagulation characteristics. These include addition of calcium chloride, reduction of the pH to 6.4 prior to renneting, through lactic acid production or addition, and reducing the amount of coagulant. The latter would best be done by objective measurements of curd formation rates using the type instrumentation described earlier. We should strive to both get the best clot out of the milk and get the worst animals out of the milk supply.

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